EXPERIMENT REQUIREMENTS DOCUMENT
FOR
REFLIGHT OF THE
SMALL HELIUM-COOLED
INFRARED TELESCOPE EXPERIMENT

NAS5-26097

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PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

BY

SMITHSONIAN INSTITUTION
ASTROPHYSICAL OBSERVATORY
60 GARDEN STREET
CAMBRIDGE, MASSACHUSETTS 02138

The Smithsonian Astrophysical Observatory
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EXPERIMENT REQUIREMENTS DOCUMENT FOR IRT REFLIGHT

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FIGURES AND TABLES

1.0 GENERAL INFORMATION

1.1 SUMMARY OF EXPERIMENT OBJECTIVES

1.1.1 Astronomical Goals -

Virtually our entire knowledge of the infrared sky pertains to relatively compact spatial structures. The space environment should permit study of large-scale structures; however, currently planned space projects for infrared astronomy -- including the IRAS sky survey -- emphasize study of compact sources. The small, cryogenically cooled, scanning telescope described here will be ideal for measuring extended sources, thereby complementing the program planned for IRAS.

This experiment addresses four astronomical objectives:

a. The measurement and mapping of extended low surface-brightness infrared emission from the galaxy. Extended far infrared radiation from the galaxy was discovered in 1968 and has subsequently been measured over 50 degrees of galactic longitude to a surface brightness of 1×10^{-11} W/cm^2 /ster at 100 microns. The Spacelab-2 experiment, more than 500 times more sensitive than current balloon experiments at 100 microns, will make possible an extensive measurement of the quantity, distribution, and temperature of galactic dust. A new understanding of galactic structure will result, including spatial scales that are essentially unexplored in the infrared for our

galaxy, but which reproduce the spatial resolution of typical studies of external galaxies.

b. The measurement of diffuse emission from intergalactic material and/or galaxies and quasistellar objects. If observations of the diffuse radiation from clusters of galaxies are coordinated with the IRAS program so that selected clusters are well-observed at high and low spatial resolution, new information will be obtained on the intergalactic medium. Such observations will be particularly interesting when they pertain to clusters known to exhibit diffuse X-ray emission.

c. The measurement of the zodiacal dust emission. Calculations indicate that zodiacal dust emission is likely to produce the major contribution to the background over much of the far infrared, if the H_2O column density can be held to less than 1×10^{12} mol/cm^2. The scanning and absolute flux measurement capability of this experiment makes it possible to measure the zodiacal emission and to distinguish it from other sources by its spectral and spatial distribution.

d. The measurement of a large number of discrete infrared sources which overlap with the results of IRAS. In order to distinguish between a true diffuse emission and the effect of one or more discrete sources in the beam, it is necessary to include spatial filtering. This provides measurements of the flux, spectral characteristics,

positions, and sizes of discrete sources with a high sensitivity. Comparison of these results with those from IRAS will provide additional information on source spatial extent and source variability.

1.1.2 Engineering Goals -

Technical and engineering objectives are primarily concerned with the measurement of the natural and spacecraft-induced infrared background, and the determination of suitable procedures and techniques for the in-space use of superfluid helium and cryogenic telescopes. In particular, these objectives are:

a. To make environmental measurements of H_2O, CO_2, and other infrared-active molecules, dust particles, and the effects of molecular deposition and cosmic rays; and to determine the effects of the induced Shuttle environment on the performance of cooled infrared telescopes.

b. To prove out the design of a cooled infrared telescope that can be applied to larger scale instruments (this includes, for example, the design of a sunshade and vacuum cover for a cooled telescope, and protection of cooled optics against condensates).

c. To demonstrate the performance of a large superfluid helium dewar system and measure certain properties of superfluid helium in space. Such aspects of cryogenic technology to be investigated include the storage and control in space of a large volume of superfluid helium, the long-term zero-g operation of a porous plug, the transfer of refrigerant to a complex thermal load.

1.1.3 Specific Goals Of The Reflight Mission -

The constraints of the SL-2 mission are such that in one flight we will not be able to complete a sky survey which includes all our prime astronomical targets, e.g., the galactic center, the galactic pole, the galactic plane, the ecliptic plane and pole, clusters of galaxies, and a search for extragalactic anisotropy. We expect about 30 hours of prime observing time during the SL-2 mission, i.e., observations under ideal conditions of minimum contamination and primary control of the Orbiter attitude. We will also not be able to observe within a radius of 35 degrees from the sun. Furthermore, if the launch of SL-2 occurs in winter we will not be able to observe the galactic center.

In terms of our engineering goals, although we will have acquired considerable data and experience on SL-2 on both contamination levels and operation of cryogenic systems, more observation time is needed on these subjects. It is important, for example, to know if the Orbiter- and

Spacelab-induced background radiation changes with each reflight. In the cryogenic system there will no doubt be minor changes in hardware and methods of operation that we shall wish to make and test.

1.2 INSTRUMENT CHARACTERISTICS

The Infrared Telescope Experiment (IRT) is composed of four major subsystems. Together they comprise a cryogenically cooled, slow scanning telescope of 15.2-cm aperture designed to measure extended infrared sources, including any halo of induced environmental contamination surrounding the Shuttle Orbiter. The actively controlled helium system also permits testing various helium-control protocols in the space environment. A block diagram is given in Figure 1.2-1. Figure 1.2-2 shows the optical layout.

1.2.1 The Telescope -

The telescope is an f/8, 15.2-cm, highly-baffled Herschelian. The entire telescope is inside a cryostat and the mirror and lower telescope section are cooled to 8 K. The aluminum off-axis paraboloid mirror is gold-coated to provide an emissivity near 0.1. A low-emissivity specular sunshade protects the aperture, blocking off-axis radiation and limiting the thermal load on the upper telescope.

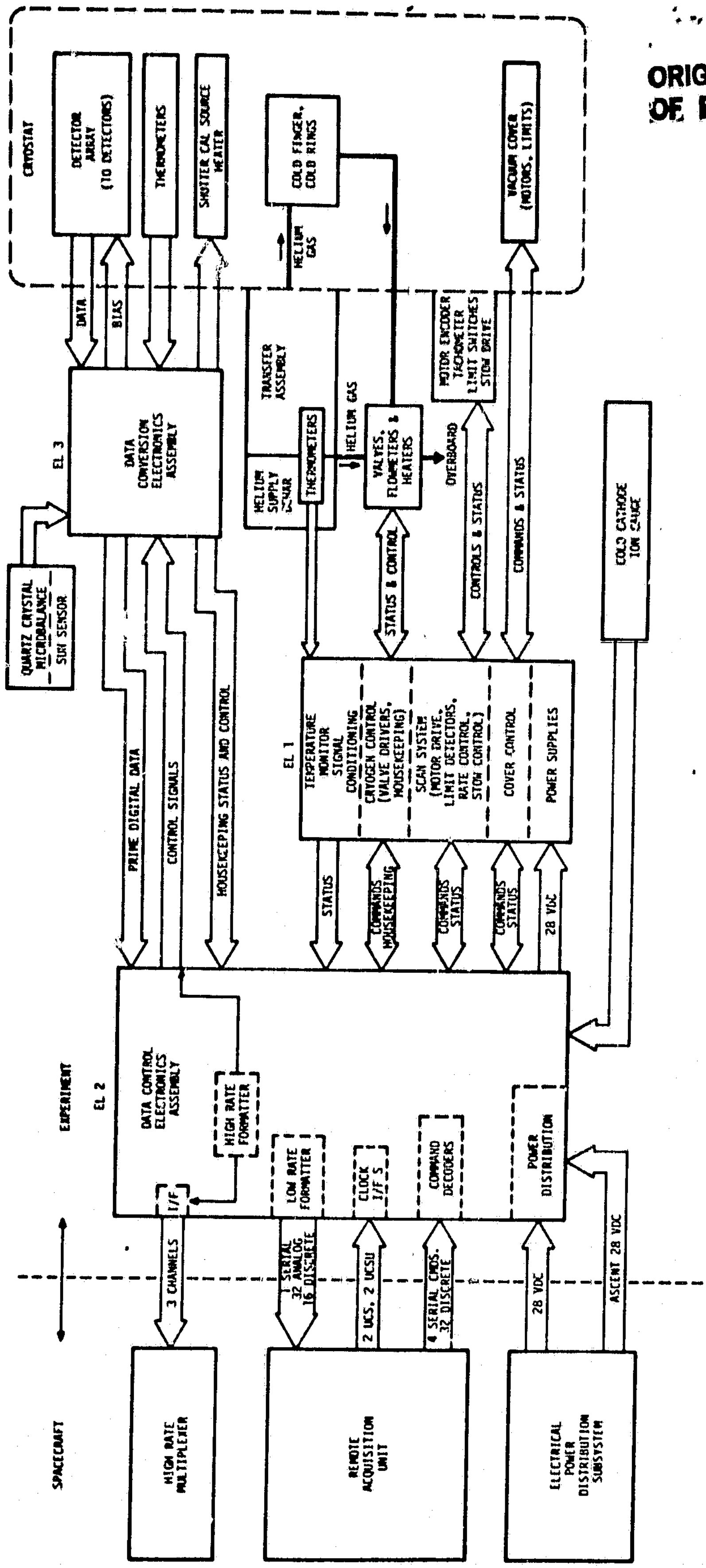


Figure 1.2-1. IRT Experiment Block Diagram

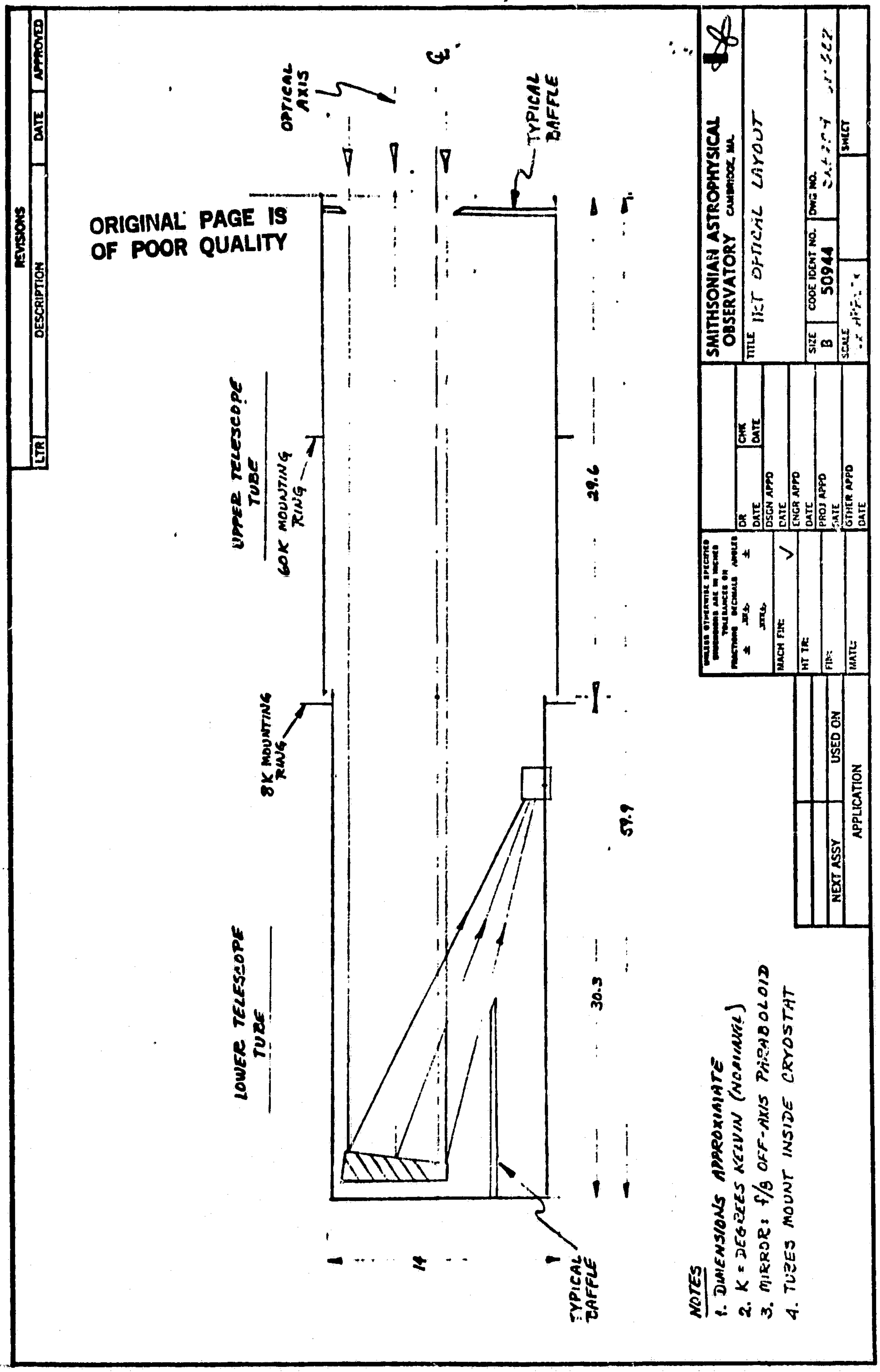


Figure 1.2-2. IRT Optical Layout

The detector blocks consist of the detectors, with associated load resistors, Fabry lenses, aperture mask and bandpass filters. Nine of the discrete photoconductors are used to cover the wavelengths 4.5 - 120 microns in five bands, each having a 0.6 x 1.0-degree field of view. A single stellar detector is used for aspect determination. A cold finger attached to the detector blocks is used to maintain the detectors at less than 3 K. The focal-plane assembly also contains a shutter maintained at 8 K. A passively-cooled vacuum cover is used to close off the cryostat while on the ground or while on orbit during periods when excess buildup of contamination would occur.

The telescope is articulated by a single-axis scan-drive system, permitting it to scan over a 90-degree angle. A ferrofluidic seal maintains the vacuum integrity between the rotating cryostat and the pallet-mounted supply dewar.

1.2.2 The Cryogenic System -

Cold helium gas derived from 250 liters of superfluid provides refrigeration. Gas flows are regulated by actively controlled valves; a porous plug serves as the phase separator to confine the fluid to the storage dewar. The entire system is vacuum jacketed for thermal protection;

when in the atmosphere the cryostat containing the telescope is sealed and evacuated to prevent contaminants from freezing onto the baffles and optical elements.

1.2.3 Electronics -

This system provides data from the telescope in an appropriate format, along with status information, to the HRM and RAU. It receives, decodes and executes commands from the RAU and operates the servo-controlled scan drive.

1.2.4 Support Structure -

This passive framework holds the other subsystems in the appropriate configuration and provides a mechanical interface with pallet hard points. All system elements are carried on the support structure except two cold-plate-mounted electronics boxes.

1.3 SUMMARY OF EXPERIMENTAL OBSERVATIONS

The required operational steps are collected into five groups called functional objectives. All commands can be originated from the AFD or POCC. Under normal operations the POCC is the preferred point of origin, except for the scan limits which are computed by the EC using the BOAA program.

Throughout this document Spacelab coordinates are used. Hence the -X direction is toward the nose of the Orbiter. See Figure 2.2-1.

FO NO.	FUNCTIONAL OBJECTIVE
1	ACTIVATE Requirements: Under normal conditions FO-1A must be accomplished by 12 hours. However, if the space vent valve V10 had not opened automatically, FO-1A must be accomplished prior to 4 hours to permit backup commanding of either V10 or V9 OPEN. FO-1B must be accomplished by 24 hours.
1A	TURN-ON (FROM AFD) Requirements: Provide power and command capability to experiment. Ensure 28-Volt DC buss power is not on. Turn on RAU 22. Issue discrete outs 3-32 OFF. Turn on EPBD 28-Volt power buss to IRT. Verify discrete in 12. Issue discrete outs 17 through 23 and 31 ON, V1 adjust to TBD and V2 adjust to TBD. Note: Cryogen adjusts will take place approximately every half hour after turn-on until the end of the mission.
1B	CHECK-OUT (FROM POCC) Requirements: Validate the functioning of the various experiment components. Verify sun alarm and BOA algorithm (-XVV attitude), verify scan drive and sun avoidance (-XVV attitude), send backup scan limits from POCC, degas QCM.
2	STANDBY Requirements: To maintain the experiment in readiness for data taking. The experiment will then be in standby until an appropriate time for taking data. The standby objective may be achieved a number of times during the mission, for example, during the first 30 hours on orbit when SL is still heavily outgassing, or when water-vapor levels are too high because of water dumps.

FO NO.	FUNCTIONAL OBJECTIVE
3	OPERATE The telescope will scan a 90-degree arc in a plane perpendicular to the Orbiter longitudinal axis. The scan rate has been selected with respect to the orbital rate such that the telescope's 3-degree field of view will, at the end of any given scan, overlap the start of the previous scan by about 1 degree. Thus in one orbit the telescope will view a continuous swath of sky 90 degrees wide, except where the scan may come within 35 degrees of the sun, moon, earth limb, or Shuttle surface (35 degrees), or within 75 degrees of the velocity vector. <u>Requirements</u>: To take data. To achieve the operate objective, a series of commands sent from the ground or from the aft flight deck would open the cover, scan the telescope, open and close the shutter as necessary, and exercise the calibration source. Coolant flow will be adjusted from time to time during both observing and nonobserving periods. The operate FO is divided into five subdivisions: 3A, 3B, 3C, 3D and 3E.
3A	OBSERVE -- BASELINE DATA <u>Requirements</u>: With Orbiter in each of three specified attitudes (-XVV XLV, -XVV Z+30 degrees, and -XVV Z-30 degrees) take data on three sequential revolutions (total of 9 revs). It is not necessary, although desirable, to take data for the 3 attitudes on contiguous triplets of revolutions.

FO NO.	FUNCTIONAL OBJECTIVE
3B	OBSERVE -- PRIME DATA TAKE Requirements: Take as much data as possible on each revolution in sets of three revolutions throughout the mission for a total of at least 18 revs observing time beyond FO 3A.
3C	OBSERVE -- COORDINATED OBSERVING Requirements: Take data in coordination with other experiments using spacecraft attitudes prescribed by them.
3D	OBSERVE -- MISCELLANEOUS OBSERVING Requirements: Take data whenever spacecraft attitude and induced environment permit.
3E	OBSERVE -- CONTROLLED CONTAMINATION Requirements: Observe contamination buildup during thruster firings, H_2O dumps, etc.
4	DEACTIVATE Requirements: To prepare the experiment for deboost. The cryostat will be secured for reentry, excess helium vented, and all electric power turned off.
5	HELIUM MANAGEMENT TEST Requirements: Permit liquid helium to warm to various temperatures above the lambda point; test repumping of system to operating temperature. These tests to be conducted late in the mission after primary infrared measurement program is completed.

1.4 MISSION CHARACTERISTICS

The IRT has no firm requirements for mission characteristics. However, several are desirable.

1. The mission should be in a season of the year different from SL-2 so that the part of the sky lost in the sun's glare during SL-2 can be observed during the reflight.

2. If new moon occurs during the mission, infrared sky coverage can be maximized.

3. Data taken during passages through the South Atlantic Anomaly are vitiated by energetic particles striking the detectors, so orbits minimizing time in the SA Anomaly are desirable.

2.0 PHYSICAL AND FUNCTIONAL REQUIREMENTS

2.1 MECHANICAL INTERFACE REQUIREMENTS

2.1.1 Drawings -

Figures 2.1.1-1,-2,-3,and -4 show the flight system assemblies and give selected interface data. Figure 2.1.1-5 shows the angular momentum exchange each time the cryostat scan is reversed.

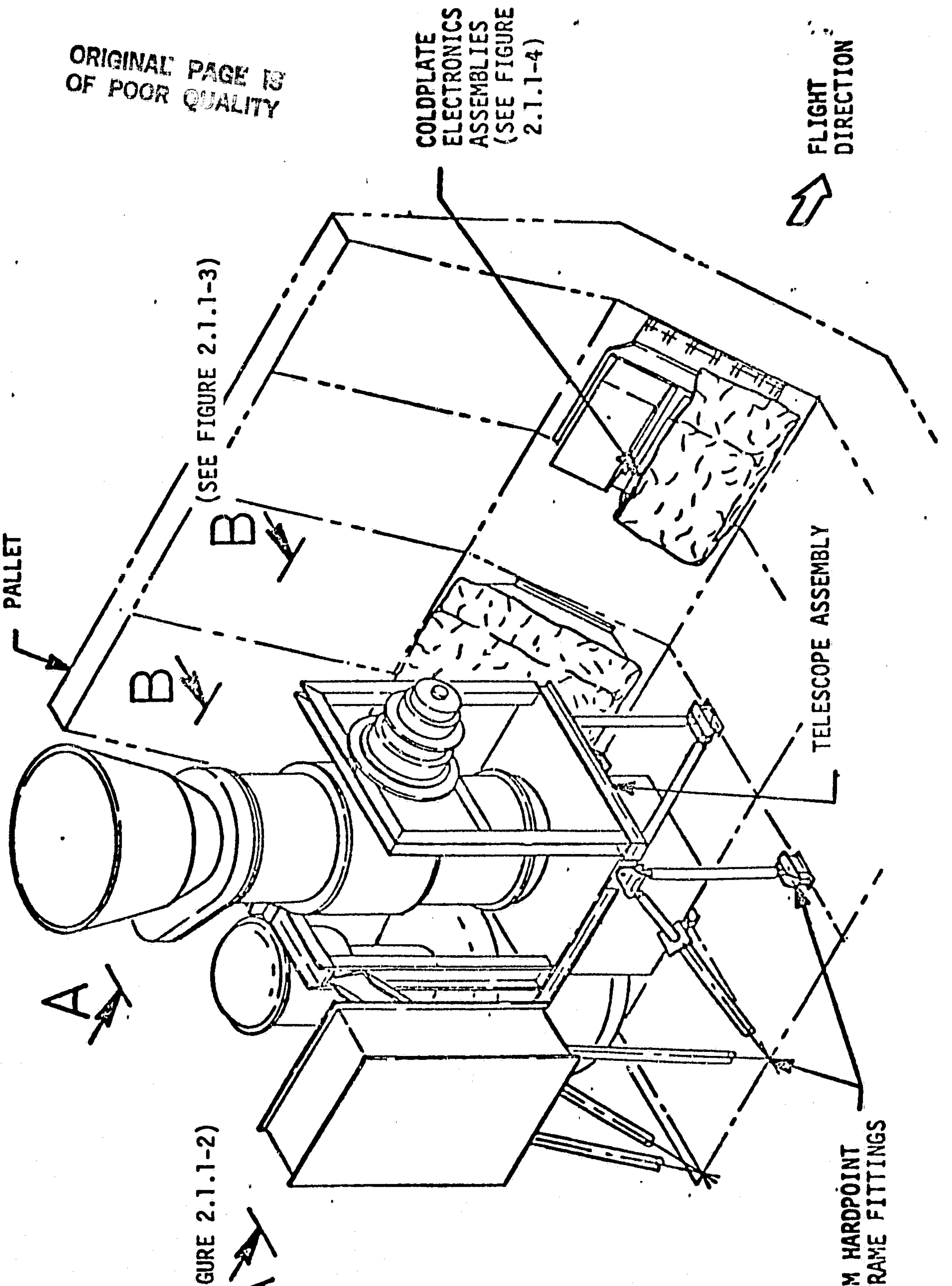
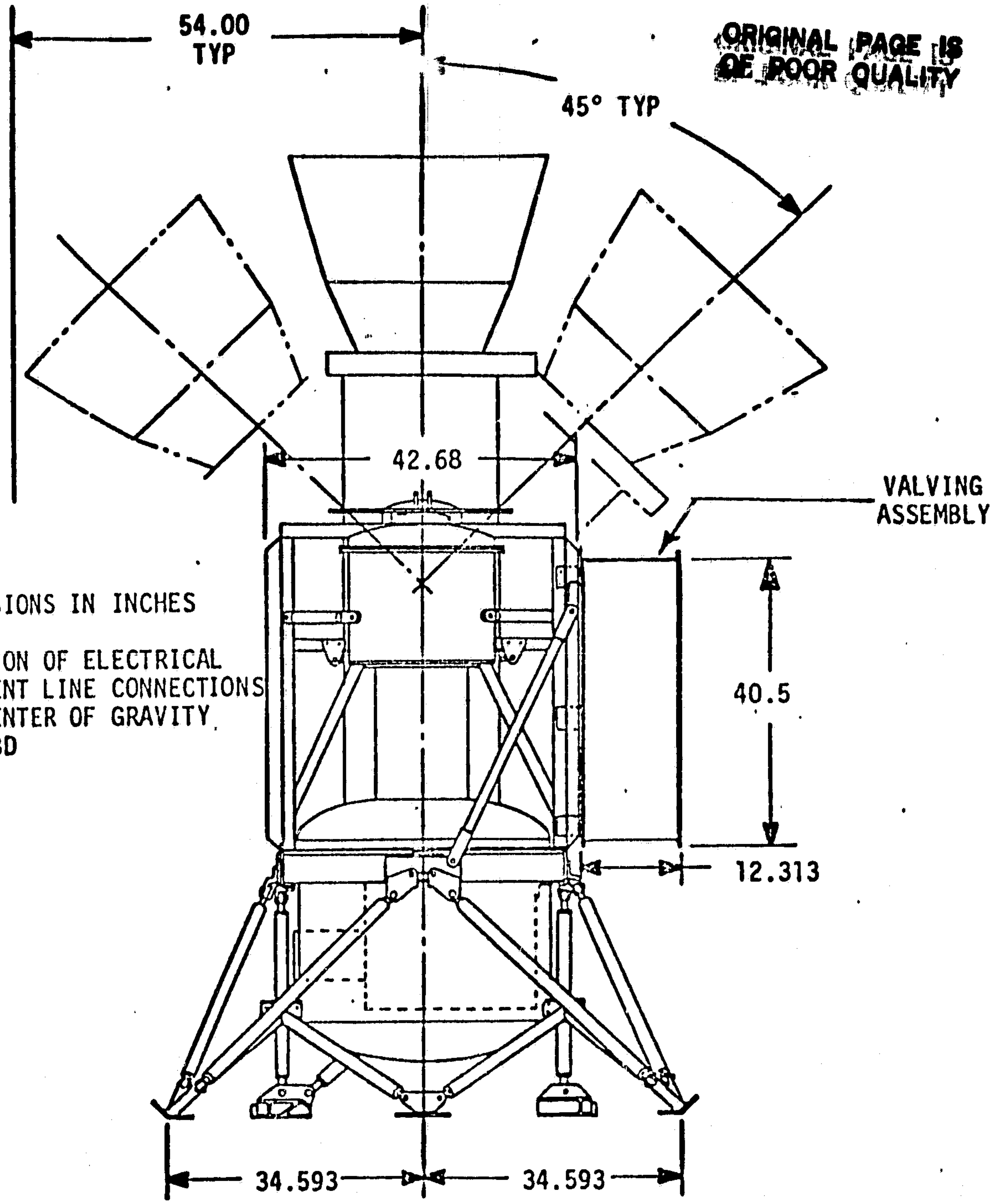


Figure 2.1.1-1. Pallet-Mounted Components



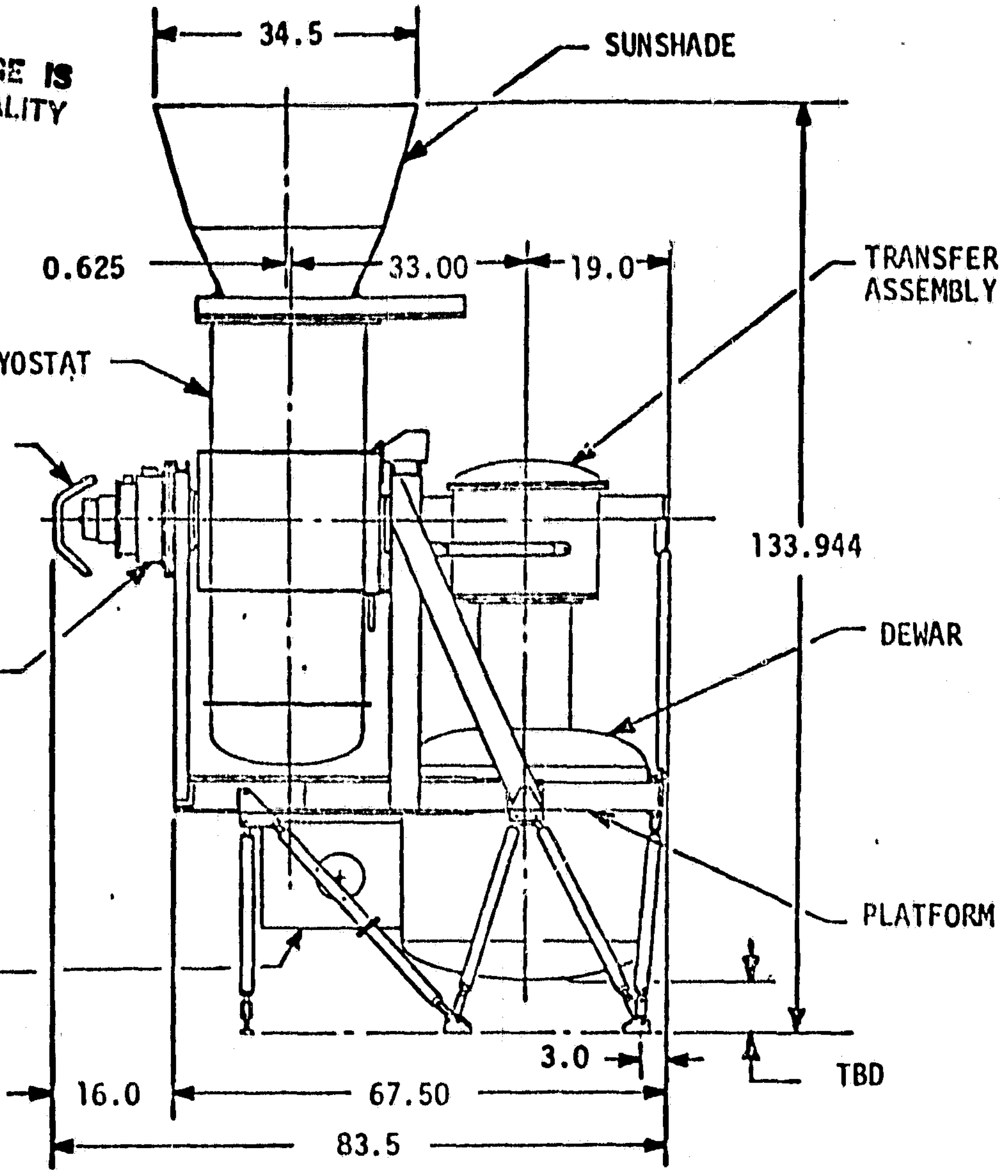
NOTE:

1. DIMENSIONS IN INCHES

2. LOCATION OF ELECTRICAL AND VENT LINE CONNECTIONS AND CENTER OF GRAVITY ARE TBD

VIEW A - A
(SEE FIGURE 2.1.1-1)

Figure 2.1.1-2. Telescope Assembly



VIEW B - B
(SEE FIGURE 2.1.1-1)

NOTES:

1. DIMENSIONS IN INCHES UNLESS OTHERWISE SPECIFIED.

2. MOUNTING PROVISIONS ARE PROVIDED BY THE EXPERIMENTER TO REPLACE PALLET HARDPOINTS.

3. LOCATION OF ELECTRICAL AND VENT LINE CONNECTIONS AND CENTER OF GRAVITY ARE TBD.

Figure 2.1.1-3. Telescope Assembly

NOTES:
1. DIMENSIONS ARE IN MM (IN.)
2. TOLERANCES ON DIMENSIONS ARE:
   .XX ± 0.508 MM (0.02 IN.)
   .XXX ± 0.127 MM (0.005 IN.)
   UNLESS OTHERWISE SPECIFIED.
3. CENTER OF GRAVITY DESIGNATED BY

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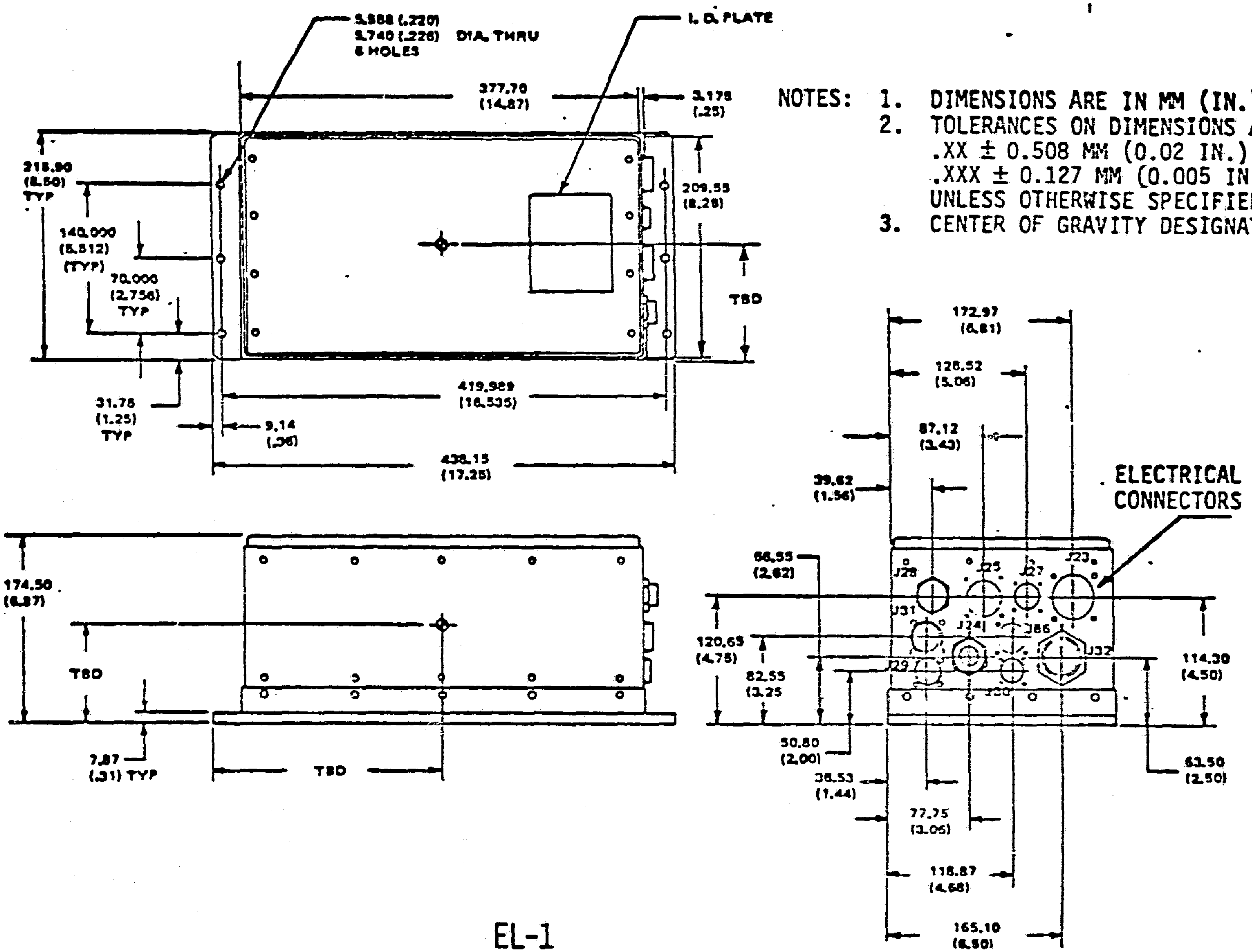
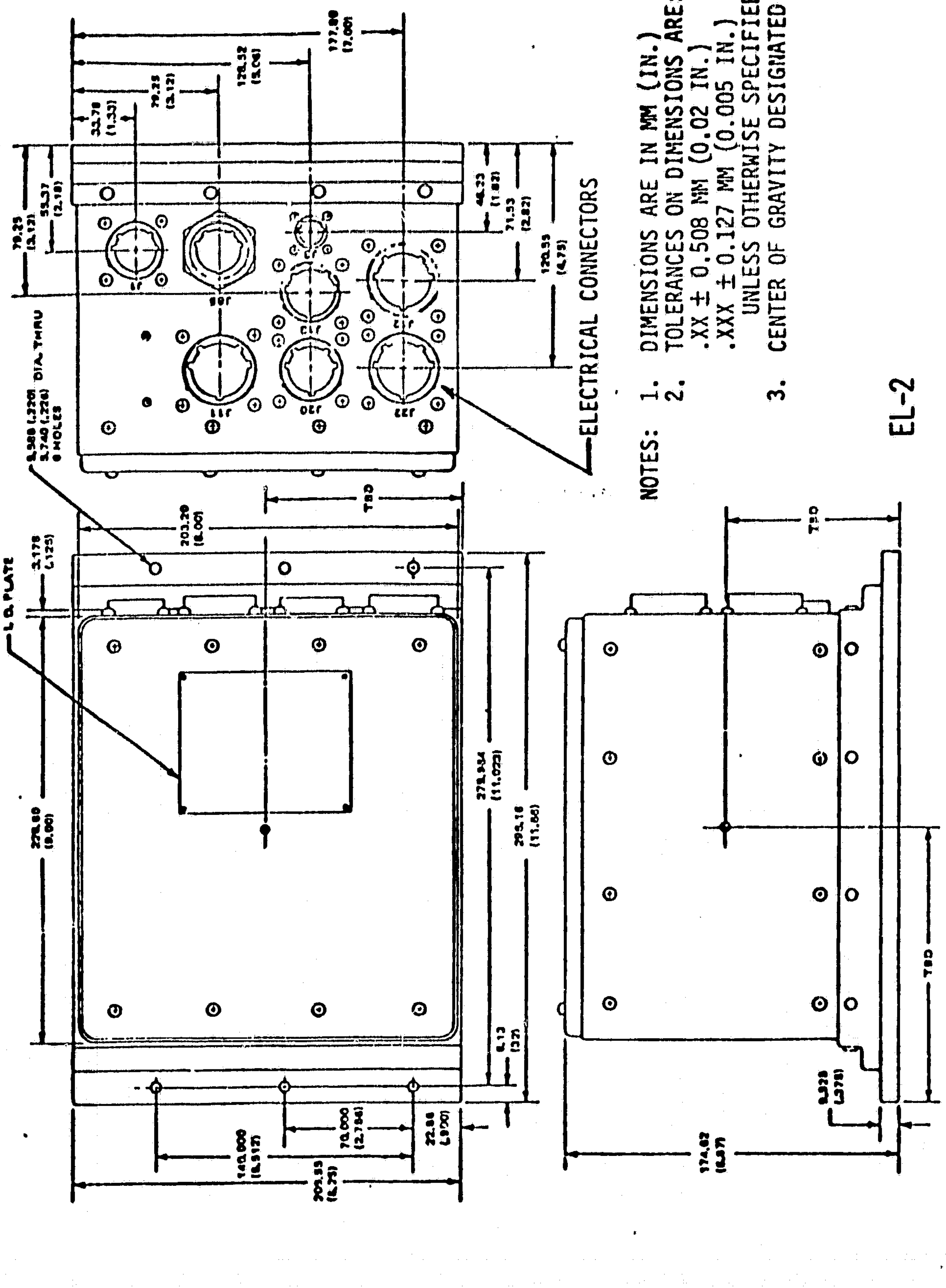


Figure 2.1.1-4. IRT Electronics Assemblies (sheet 1 of 2)



NOTES:
1. DIMENSIONS ARE IN MM (IN.)
2. TOLERANCES ON DIMENSIONS ARE:
   .XX ± 0.508 MM (0.02 IN.)
   .XXX ± 0.127 MM (0.005 IN.)
   UNLESS OTHERWISE SPECIFIED
3. CENTER OF GRAVITY DESIGNATED BY

EL-2

Figure 2.1.1-4. IRT Electronics Assemblies (sheet 2 of 2)

TBD

Figure 2.1.1-5. Angular Momentum Exchange

2.1.2 Flight Equipment -

Flight Equipment properties are shown in Table 2.1.2-1.

Table 2.1.2-1
Flight Equipment Properties

MODULE EQUIPMENT - NONE

PALLET EQUIPMENT

ID No.	Nomenclature	Mass(kg)	Dimensions(in.)	Mounting	CG
42A20140	IRT SYSTEM Telescope Assembly	751.5	83.5 x 69 x 134	Pallet Hardpoints	TBD
5061101	Electronics Box EL-1	9.1 (est.)	17 x 8.5 x 7	Cold Plate	TBD
5061202	Electronics Box EL-2	9.1 (est.)	12 x 8 x 7	Cold Plate	TBD

AFD EQUIPMENT - NONE

2.1.3 Alignment Requirements -

Bolt hole alignment is satisfactory.

2.1.4 Deployment Requirements -

Although the system has a stow pin it is not safety critical; there are no deployment requirements.

2.2 ATTITUDE REQUIREMENTS

To accomplish the scientific objectives of the experiment, that is, to produce large-scale infrared maps, it is necessary for this instrument to scan the sky about two axes. Figure 2.2-1 illustrates the solid angle scanned relative to the Orbiter. Precisely, the telescope is driven about a single axis which is parallel to the payload X-axis, that is, in the Y-Z plane. Nominally it scans within ± 45 degrees of the vertical, that is, 45 degrees from the payload X-Z plane. The scan rate is fixed at 6 deg/sec. The turnaround at the end of each scan is accomplished in 1 sec. The scan limits are variable so as to avoid bright infrared objects, such as the sun, moon, and earth. In concert with the telescope scan about the Orbiter X-axis, the Orbiter must <u>continuously</u> and <u>uniformly</u> pitch about its Y-axis so as to maintain the payload Y-Z plane (the scan plane) nominally parallel with the nadir (local vertical). This has been referred to as the airplane mode or -XVV,ZLV, that is, the X-axis along the velocity vector and Z-axis along the local vertical (nose first, payload pointing away from the earth).

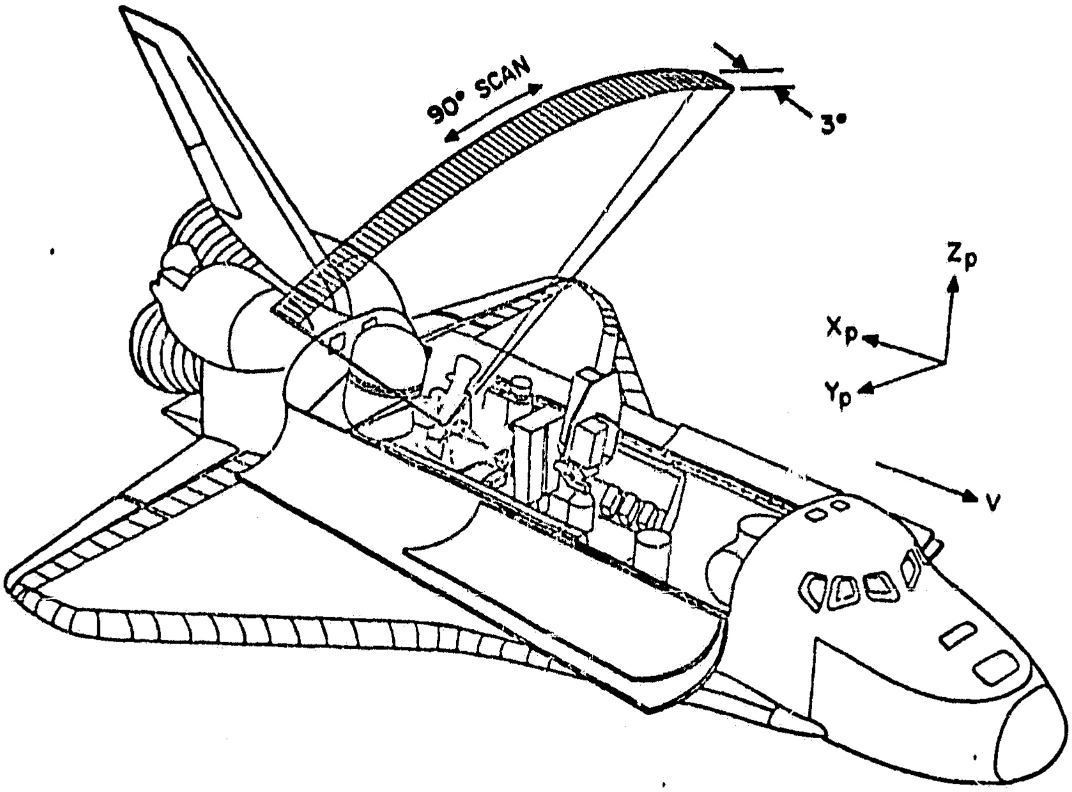


Figure 2.2-1. Telescope scan pattern in relation to the Spacelab; preferred orbital attitudes, -XVV with ZLV and Z±30.

To reduce contamination due to streaming of material into the telescope, it is required to have the nose slightly up, by about 2.5 degrees, i.e., -XVV+2.5.

In order to map as much of the sky as possible in a single mission it is required to roll the Orbiter ± 30 degrees about the X-axis, providing coverage of a 150-degree band of the sky centered on the orbital plane, exclusive of the sun (and new moon). These attitudes are referred to as -XVV+2.5,ZLV+30 and -XVV+2.5,ZLV-30, along with -XVV+2.5,ZLV.

These three attitudes are required to carry out the primary scientific objectives.

2.3 ELECTRICAL REQUIREMENTS

2.3.1 Power Profiles -

Figures 2.3.1-1, 2.3.1-2 and 2.3.1-3 are typical IRT power profiles. Note that these apply to the electrical configuration for Spacelab 2. An electronics change under consideration may result in a somewhat different profile. No equipment is on the AFD. There is no profile for FO4 because no power is consumed.

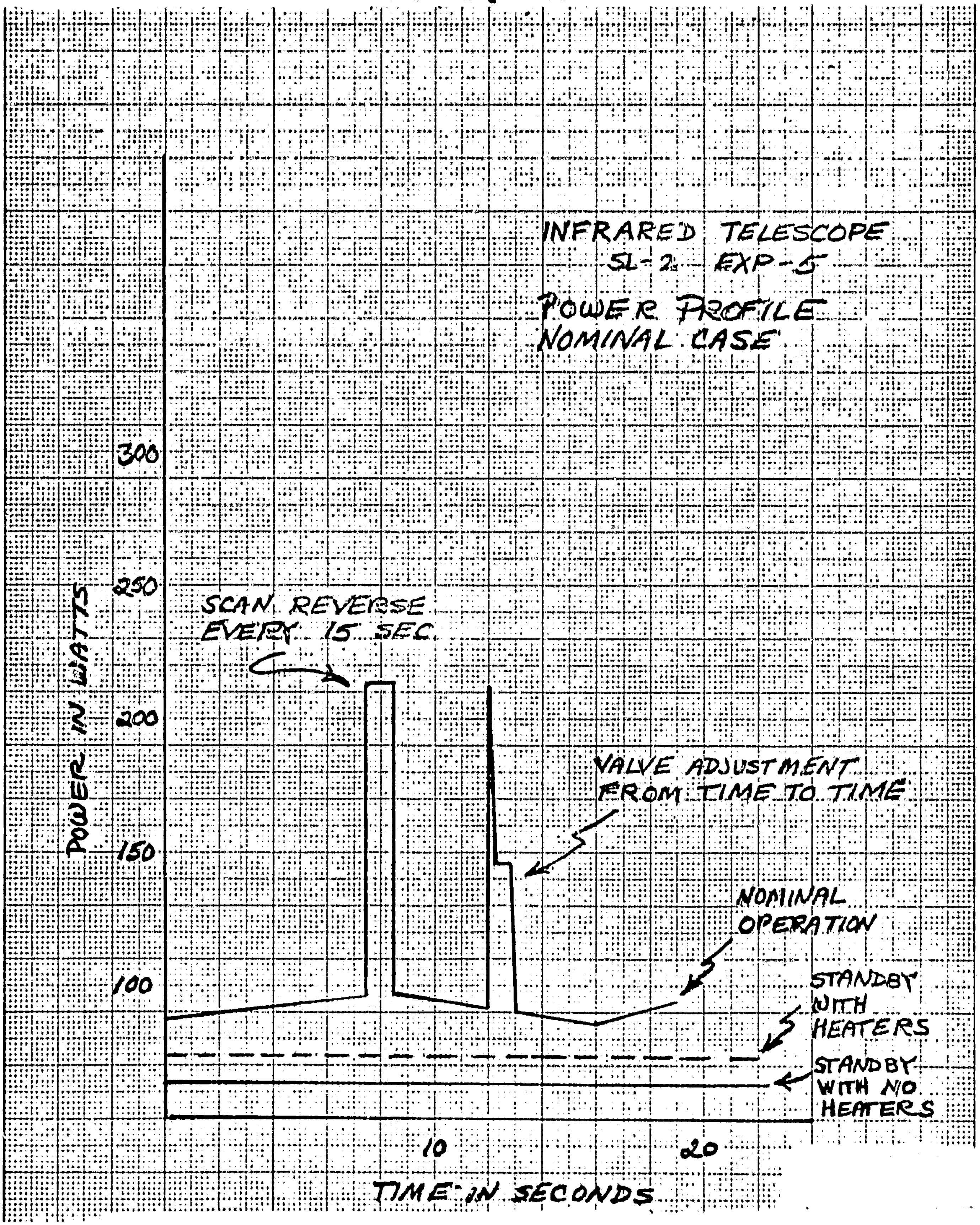


Figure 2.3.1-1. IRT Power Profile: Nominal Case

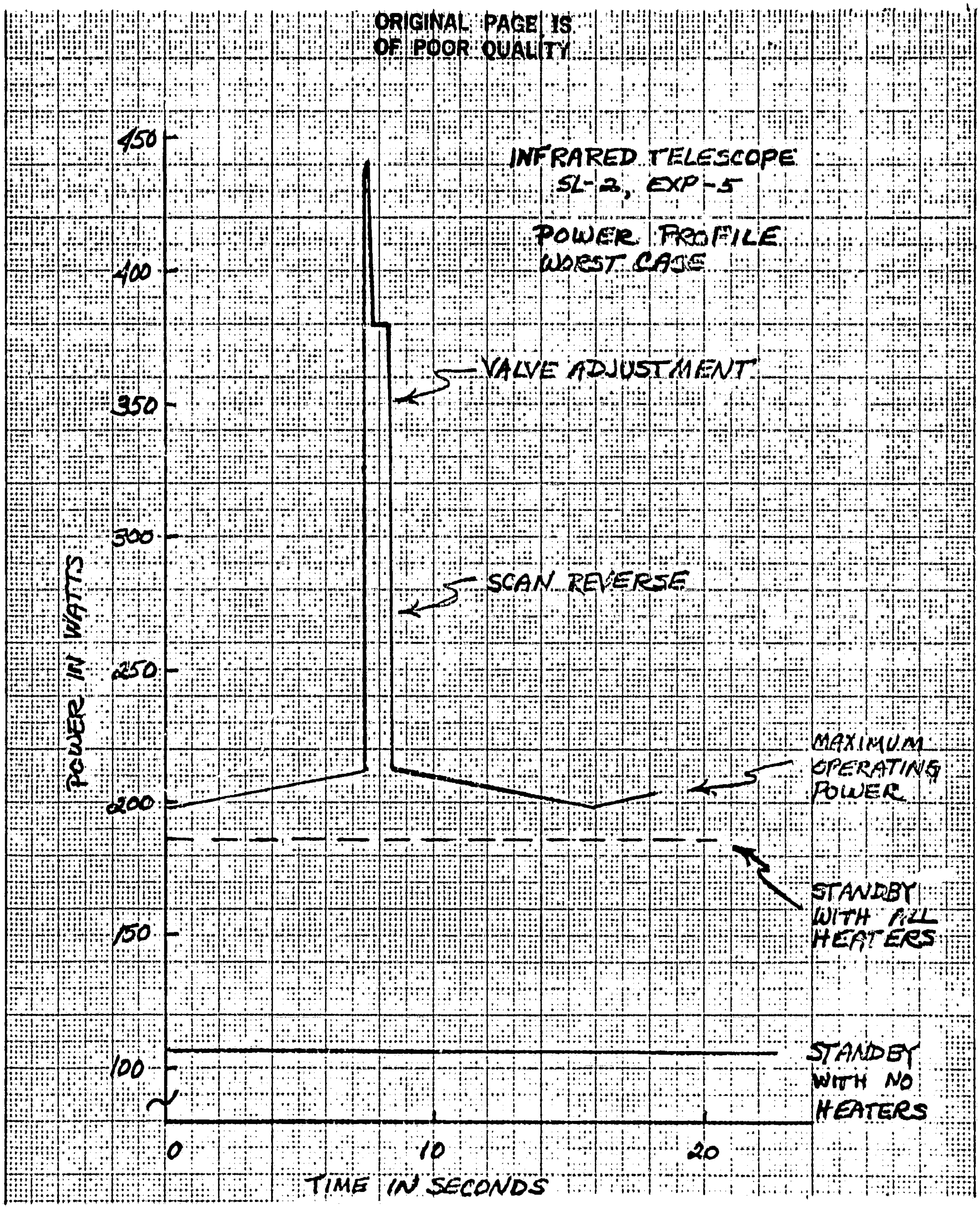


Figure 2.3.1-2. IRT Power Profile: Worst Case

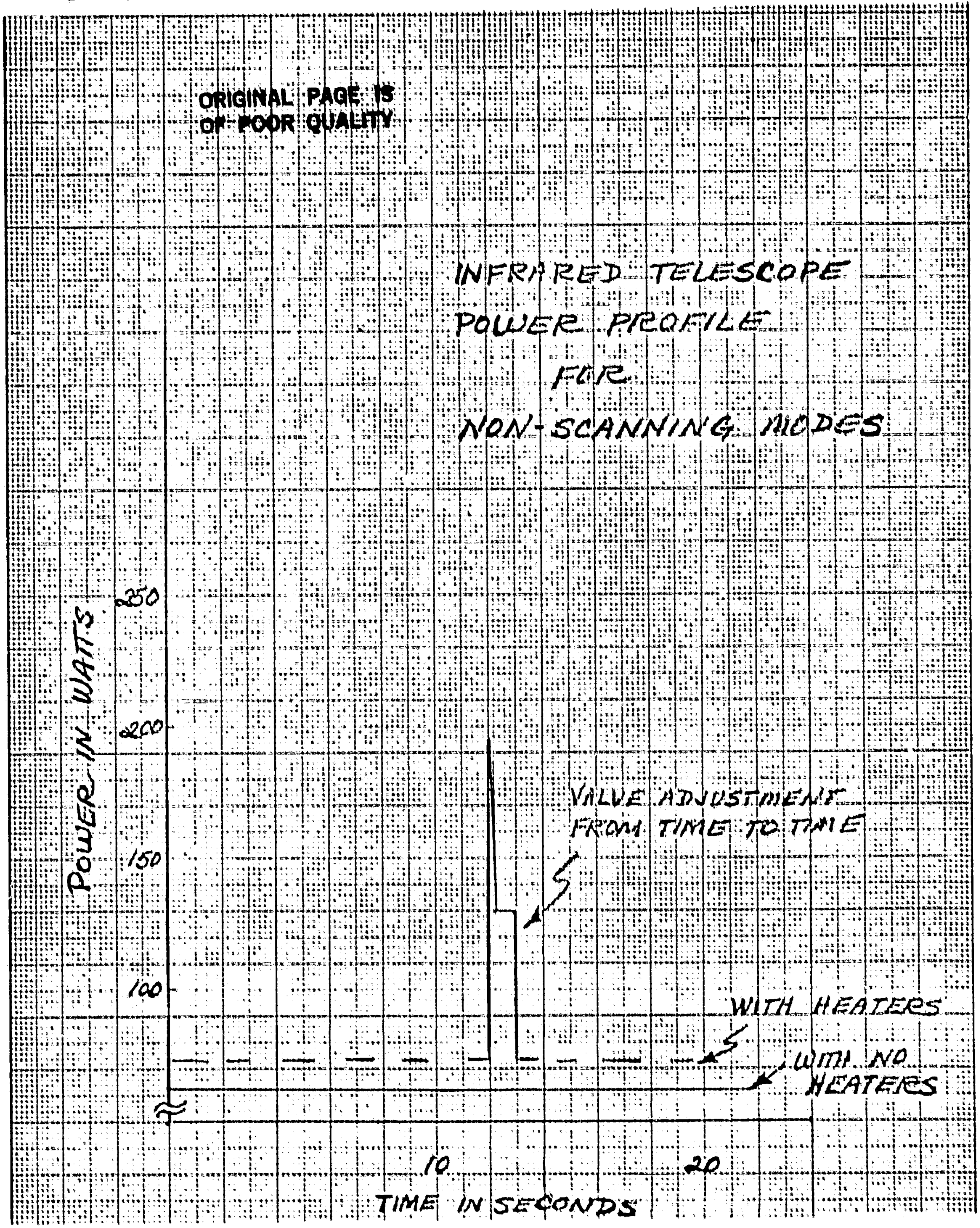


Figure 2.3.1-3. IRT Power Profile: Non-Scanning Modes

2.3.2 Connector Requirements -

IRT connectors are detailed in Table 2.3.2-1. Pin designations are in Table 2.3.2-2 (TBD).

Table 2.3.2-1
Interface Connector Requirements

IRT Subsystem	IRT-Mounted Connector	Mating Connector	Function
EL-2 J1	M83723-22R2015N	M83723-23R2015N	Power
EL-2 J3	M83723-02R1006N	M83723-13K1006N	Ascent Power
VMA J2	M83723-22R2015N	M83723-23R2015N	Ground Power via T-0 Umbilical
EL-2 J11	MS27497E24F35P	MS27484E24F35S	RAU Signals
EL-2 J12	MS27497E24F35P	MS27484E24F35S	RAU Signals
EL-2 J13	MS27497E18F35P	MS27484E18F35S	RAU Signals
VMA J1	MS83723-02R1419N	MS83723-13R1419N	Ground Power and Signals via T-0 Umbilical

NOTE

Spacelab-2 protocol calls for the experimenter to provide the IRT-mounted connectors, NASA to provide the mating connectors as MPE. As a result SAO will not have mating connectors for the reflight unless special arrangements are made.

2.3.3 Additional Requirements -

No other special requirements have been identified.

2.4 THERMAL CONTROL REQUIREMENTS

2.4.1 Thermal Control Characteristics -

TBD

2.4.2 Coatings And Coverings -

TBD

2.4.3 Cold Plate Requirements -

Electronics boxes EL-1 and EL-2 are cold-plate mounted. Dimensions and mounting data are in Section 2.1.1. Their combined heat dissipation into the freon system is estimated to be 100 watts operating and 50 watts in standby.

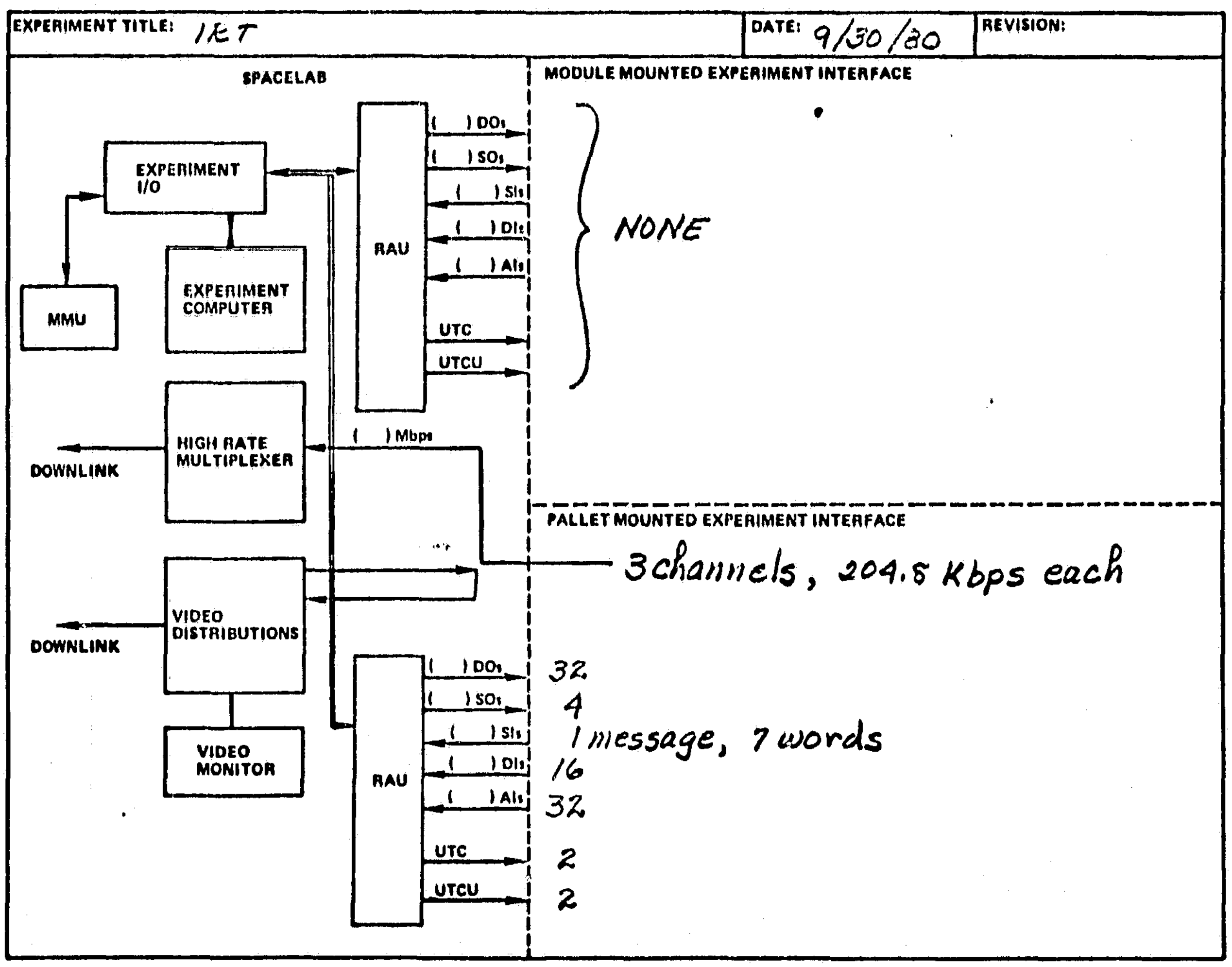
2.5 COMMAND AND DATA MANAGEMENT

It is important to note that the IRT's CDMS interface is the subject of a study being conducted by SAO. As a result, a DEP may be added to the flight system resulting in major changes to the CDMS interface. In this section we describe the current interface; future revisions <u>may</u> contain changes in keeping with the addition of a DEP.

2.5.1 CDMS Interface -

Details of the CDMS interface are given in Table 2.5.1-1.

Table 2.5.1-1
Experiment/CDMS Interface



2.5.2 Experiment Inputs -

All experiment inputs are described in detail in IRT-109, "Command and Housekeeping Definition" (see Appendix A). There are 32 discrete commands and 4 serial commands. The frequency at which various commands are issued depends entirely on mission profile, but will be of the order of one command every few minutes during FO1 and FO3, much less during other FO's.

2.5.3 Experiment Outputs -

IRT experiment outputs are described in two documents. Housekeeping is detailed in IRT-109, "Command and Housekeeping Definition." There are 16 discretes, 32 analogs, and one serial message. In addition, selected housekeeping data are transmitted via the HRM along with all infrared science data. The HRM output is described in IRT-116, "HRM Format Description" (see Appendix B). The three HRM frame formats are shown in detail in Figures 2.5.3-1, 2.5.3-2, and 2.5.3-3.

FRAME NUMBER

GMT FIRST 6 FRAMES

BYTE NO.

SYNC CODE AND FRAME NO.		GMT WORD #N	DETECTOR B HI	DETECTOR B MID	DETECTOR B LO	DETECTOR A HI	DETECTOR A MID	DETECTOR A LO	DETECTOR D-1 HI
DETECTOR D-1 MID	DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID	DETECTOR E-1 LO	DETECTOR B HI	DETECTOR B MID	DETECTOR B LO	DETECTOR A HI	DETECTOR A MID
DETECTOR A LO	DETECTOR D-1 HI	DETECTOR D-1 MID	DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID	DETECTOR E-1 LO	DETECTOR B HI	DETECTOR B MID	DETECTOR B LO
DETECTOR A HI	DETECTOR A MID	DETECTOR A LO	DETECTOR D-1 HI	DETECTOR D-1 MID	DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID	DETECTOR E-1 LO	DETECTOR B HI
DETECTOR B MID	DETECTOR B LO	DETECTOR A HI	DETECTOR A MID	DETECTOR A LO	DETECTOR D-1 HI	DETECTOR D-1 MID	DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID
DETECTOR E-1 LO	STATE VECTOR WORD #N	DETECTOR B HI	DETECTOR B MID	DETECTOR B LO	DETECTOR A HI	DETECTOR A MID	DETECTOR A LO	DETECTOR D-1 HI	DETECTOR D-1 MID
DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID	DETECTOR E-1 LO	DETECTOR B HI	DETECTOR B MID	DETECTOR B LO	DETECTOR A HI	DETECTOR A MID	DETECTOR A LO
DETECTOR D-1 HI	DETECTOR D-1 MID	DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID	DETECTOR E-1 LO	DETECTOR B HI	DETECTOR B MID	DETECTOR B LO	DETECTOR A HI
DETECTOR A MID	DETECTOR A LO	DETECTOR D-1 HI	DETECTOR D-1 MID	DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID	DETECTOR E-1 LO	DETECTOR B HI	DETECTOR B MID
DETECTOR B LO	DETECTOR A HI	DETECTOR A MID	DETECTOR A LO	DETECTOR D-1 HI	DETECTOR D-1 MID	DETECTOR D-1 LO	DETECTOR E-1 HI	DETECTOR E-1 MID	DETECTOR E-1 LO

Note: For detailed information, see HRM Format Description, IRT-116

Figure 2.5.3-1. HRM Frame Format 1

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FRAME NUMBER

GMT FIRST 6 FRAMES

BYTE No.

← SYNC CODE AND FRAME No. →		GMT WORD # N	← DIGITAL HOUSEKEEPING →	← LIMITS →	← SCAN ENCODER →	DETECTOR S HI	DETECTOR S MID	DETECTOR S LO	DETECTOR D-2 HI
DETECTOR D-2 MID	DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID	DETECTOR E-2 LO	← DIGITAL HOUSEKEEPING →	← LIMITS →	← SCAN ENCODER →	DETECTOR S HI	DETECTOR S MID
DETECTOR S LO	DETECTOR D-2 HI	DETECTOR D-2 MID	DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID	DETECTOR E-2 LO	← DIGITAL HOUSEKEEPING →	← LIMITS →	← SCAN ENCODER →
DETECTOR S HI	DETECTOR S MID	DETECTOR S LO	DETECTOR D-2 HI	DETECTOR D-2 MID	DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID	DETECTOR E-2 LO	← DIGITAL HOUSEKEEPING →
← LIMITS →	← SCAN ENCODER →	DETECTOR S HI	DETECTOR S MID	DETECTOR S LO	DETECTOR D-2 HI	DETECTOR D-2 MID	DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID
DETECTOR E-2 LO	← STATE VECTOR WORD # N →	← DIGITAL HOUSEKEEPING →	← LIMITS →	← SCAN ENCODER →	DETECTOR S HI	DETECTOR S MID	DETECTOR S LO	DETECTOR D-2 HI	DETECTOR D-2 MID
DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID	DETECTOR E-2 LO	← DIGITAL HOUSEKEEPING →	← LIMITS →	← SCAN ENCODER →	DETECTOR S HI	DETECTOR S MID	DETECTOR S LO
DETECTOR D-2 HI	DETECTOR D-2 MID	DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID	DETECTOR E-2 LO	← DIGITAL HOUSEKEEPING →	← LIMITS →	← SCAN ENCODER →	DETECTOR S HI
DETECTOR S MID	DETECTOR S LO	DETECTOR D-2 HI	DETECTOR D-2 MID	DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID	DETECTOR E-2 LO	← DIGITAL HOUSEKEEPING →	← LIMITS →
← SCAN ENCODER →	DETECTOR S HI	DETECTOR S MID	DETECTOR S LO	DETECTOR D-2 HI	DETECTOR D-2 MID	DETECTOR D-2 LO	DETECTOR E-2 HI	DETECTOR E-2 MID	DETECTOR E-2 LO

Note: For detailed information, see HRM Format Description, IRT-116

Figure 2.5.3-2. HRM Frame Format 2

FRAME NUMBER

GMT FIRST 6 FRAMES

BYTE NO.

1 2 SYNC CODE AND FRAME NO.	3 4	5 6 GMT WORD #N	7 8 DIGITAL HOUSEKEEPING	9 10 LIMITS	11 12 SCAN ENCODER	13 14 DETECTOR C HI	15 16 DETECTOR C MID	17 18 DETECTOR C LO	19 20 DETECTOR D-3 HI
21 22 DETECTOR D-3 MID	23 24 DETECTOR D-3 LO	25 26 DETECTOR E-3 HI	27 28 DETECTOR E-3 MID	29 30 DETECTOR E-3 LO	31 32 DIGITAL HOUSEKEEPING	33 34 LIMITS	35 36 SCAN ENCODER	37 38 DETECTOR C HI	39 40 DETECTOR C MID
41 42 DETECTOR C LO	43 44 DETECTOR D-3 HI	45 46 DETECTOR D-3 MID	47 48 DETECTOR D-3 LO	49 50 DETECTOR E-3 HI	51 52 DETECTOR E-3 MID	53 54 DETECTOR E-3 LO	55 56 DIGITAL HOUSEKEEPING	57 58 LIMITS	59 60 SCAN ENCODER
61 62 DETECTOR C HI	63 64 DETECTOR C MID	65 66 DETECTOR C LO	67 68 DETECTOR D-3 HI	69 70 DETECTOR D-3 MID	71 72 DETECTOR D-3 LO	73 74 DETECTOR E-3 HI	75 76 DETECTOR E-3 MID	77 78 DETECTOR E-3 LO	79 80 DIGITAL HOUSEKEEPING
81 82 LIMITS	83 84 SCAN ENCODER	85 86 DETECTOR C HI	87 88 DETECTOR C MID	89 90 DETECTOR C LO	91 92 DETECTOR D-3 HI	93 94 DETECTOR D-3 MID	95 96 DETECTOR D-3 LO	97 98 DETECTOR E-3 HI	99 100 DETECTOR E-3 MID
101 102 DETECTOR E-3 LO	103 104 STATE VECTOR WORD #N	105 106 DIGITAL HOUSEKEEPING	107 108 LIMITS	109 110 SCAN ENCODER	111 112 DETECTOR C HI	113 114 DETECTOR C MID	115 116 DETECTOR C LO	117 118 DETECTOR D-3 HI	119 120 DETECTOR D-3 MID
121 122 DETECTOR D-3 LO	123 124 DETECTOR E-3 HI	125 126 DETECTOR E-3 MID	127 128 DETECTOR E-3 LO	129 130 DIGITAL HOUSEKEEPING	131 132 LIMITS	133 134 SCAN ENCODER	135 136 DETECTOR C HI	137 138 DETECTOR C MID	139 140 DETECTOR C LO
141 142 DETECTOR D-3 HI	143 144 DETECTOR D-3 MID	145 146 DETECTOR D-3 LO	147 148 DETECTOR E-3 HI	149 150 DETECTOR E-3 MID	151 152 DETECTOR E-3 LO	153 154 DIGITAL HOUSEKEEPING	155 156 LIMITS	157 158 SCAN ENCODER	159 160 DETECTOR C HI
161 162 DETECTOR C MID	163 164 DETECTOR C LO	165 166 DETECTOR D-3 HI	167 168 DETECTOR D-3 MID	169 170 DETECTOR D-3 LO	171 172 DETECTOR E-3 HI	173 174 DETECTOR E-3 MID	175 176 DETECTOR E-3 LO	177 178 DIGITAL HOUSEKEEPING	179 180 LIMITS
181 182 SCAN ENCODER	183 184 DETECTOR C HI	185 186 DETECTOR C MID	187 188 DETECTOR C LO	189 190 DETECTOR D-3 HI	191 192 DETECTOR D-3 MID	193 194 DETECTOR D-3 LO	195 196 DETECTOR E-3 HI	197 198 DETECTOR E-3 MID	199 200 DETECTOR E-3 LO

Note: For detailed information, see HRM Format Description, IRT-116

Figure 2.5.3-3. HRM Frame Format 3

2.5.4 <u>Other</u> -

No other materials are carried on an IRT mission.

2.6 SERVICE REQUIREMENTS

2.6.1 <u>Pre-Level IV Requirements</u> -

It may be necessary to run a thorough functional test at KSC prior to Level IV. This will require approximately 500 liters of liquid helium and a vent line to the outside. The flow in the vent line is a few liters of room-temperature gaseous helium per hour (maximum). All necessary vacuum pumps, heaters, etc., are experiment provided.

Round-the-clock power and access are required when the experiment contains liquid helium.

2.6.2 <u>Level-IV Requirements</u> -

IRT functional testing, compatibility testing, and detailed mission simulations require that the IRT flight system be cryogenically cooled. A supply of liquid helium is required, the amount depending upon the number and durations of cooldowns. (It is desirable to minimize the number of cooldowns.) A vent line for room-temperature

gaseous helium flowing at a few liters per hour is required. Continuous power and round-the-clock access to the experiment are necessary whenever it contains liquid helium.

2.6.3 Level-I Requirements -

The final loading of liquid helium will be conducted in the Orbiter processing facility (OPF). Room-temperature gaseous helium will flow from an appropriate Orbiter vent. Continuous 115-VAC power must be applied via the T-0 umbilical. (Interruptions not longer than five hours can be tolerated.) Round-the-clock access to the experiment or its remote control box is necessary.

3.0 EXPERIMENT OPERATIONAL PROCEDURES

This section provides the operational procedures that must be supported by NASA-provided software. It should be noted that these requirements may be substantially altered by the addition of a DEP, now under study at SAO.

3.1 TEST PROCEDURES

Prior to delivery to Level IV all testing and calibration will be controlled and monitored by IRT-provided GSE.

From Level IV through the mission all functional tests, compatibility tests, interface verification tests, and mission simulations are TBD.

3.2 MONITORING REQUIREMENTS

IRT status parameters are defined in IRT-109, "Command and Housekeeping Definition."

No hazardous conditions are indicated and no unusual displays are required. The following input signals are to be exception monitored by ECOS at 1 sps rate:

1.	DI2	Command Interlock
2.	DI9	Sun Alarm
3.	DI10	Pressure Alarm
4.	DI11	V10 Status Open
5.	AI1	Dewar Liquid Temperature
6.	AI5	Porous Plug Liquid Temperature
7.	AI24	Cryo Vent Line Pressure
8.	AI25	Dewar Vent Line Pressure
9.	SI1,W3,P1	V9 Open

In addition, as described in Section 3.4 Displays, there is an ECAS monitor of V1 + V2. Diagnostic procedures are TBD.

3.3 OPERATIONAL PROCEDURES

3.3.1 Commands And Command Sequences -

The IRT has been designed to require very few commands and command sequences. In the normal mode nothing is time critical except to avoid operating more than one valve a time and to avoid pointing directly at the sun. For example, there are 30 discrete commands of which only one is normally used. The rest deal with initial configuration, landing configuration and various anomalous situations. Serial commands to control valves and the cold shutter will be used somewhat more often.

A sequence of valve commands will be generated by ECAS whenever it is necessary to adjust the flow of cold helium gas. From one to six valves will have to be operated, each requiring a separate command with an appropriate delay between commands to avoid operating more than one valve at a time. Each sequence will be initiated by command from the AFD or POCC, with the POCC being the preferred source.

3.3.2 Coordination Of Commands With Other Events -

All commands originating from the POCC will be coordinated by the mission timeline or in response to an anomalous situation. In most cases the timelined command will be simply to start or stop scanning. Anomalous changes in internal temperature, for example, will call for a valve adjustment.

Some coordination will be required to accomplish FO3C and FO3E. In the first case observing simulataneously with another investigator will demand not only time coordination but also target location. In the second case the timing of selected Orbiter functions such as flash evaporator operation will be required so that the IRT can monitor any changes in the induced environment that may be associated with that Orbiter function.

3.3.3 Limit Conditions -

The major limit conditions requiring crew or POCC intervention are exception monitored, nine by ECOS and one by ECAS. They are listed in Section 3.2.

In addition, there my be unpredictable, although slow, variations in the internal temperature of the cryostat. These temperatures are displayed in the POCC and on the AFD (displays 5OP and 5TH). POCC intervention is the preferred mode.

3.4 DISPLAYS

Tables 3.4-1 and 3.4-2 illustrate the types of displays needed. The first set are typical for the POCC and KSC, the second set are for the AFD. Special processing to support the AFD displays includes:

1. Maintaining a command-received counter.
2. Perform valve control logic sequencing.
3. Perform limit sensing on the combined V1 + V2.
4. Receive and maintain the dewar liquid volume data.
5. Compute the flow rates.
6. Perform the cal cycle sequence.
7. Activate the porous plug heater for specified time.
8. Perform the Bright Object Avoidance Algorithm (BOAA).

Items 1, 3, 4 and 8 must be in permanent ECAS. Items 2, 6

and 7 can share the same allocated space. Item 5 need only be computed when the fifth display is allocated. All computations need not be updated more often than 1 Hz.

BOAA is defined in Section 3.5.5.2 of MSFC document JA-035, "Spacelab Mission Two Software Requirements Document."

Prelaunch and AFD displays are shown in Tables 3.4-1 and 3.4-2. They are fully defined and explained in JA-035 and in JA-032, "Ground Integration Requirements Document."

```
GMT DDD/HH:MM:SS.SSS          DP....
     5 TH    05 IRT THERMAL/VALVE
                  CMD REVD:                          DI1            0/1  CNT:  PCU  17495   ECAS     16231
     AI                                    UT        AI                                 UT       ATR      STAT        P
      1       DEWAR LIQUID     x1.8        K         17     CRYO VENT LIN     260      K        1 TCB    0/1         9
      2       DEWAR 20K VCS    x25         K         18     DEWR VENT LIN     265      K        2 JFET   0/1        10
      3       DEWAR 60K VCS    x63         K         19     SCAN MOTOR        280      K        3 PLUG   0/1        11
      4       DEWR 120K VCS    112         K         20     THERM CONT EX     281      K        4 SCAN   0/1        12
      5       PORUS PLG LIQ    x1.8        K         21     DEWAR SHELL       260      K        5 PIN    0/1        13
      6       PORUS PLG VAP    x1.8        K         22     SUNSHADE          301      K        6 EL3    0/1        14
      7       COLD FINGER      x2.4        K         23     QCM AMBIENT       290      K        7 TACH   0/1        15
      8       CRYO 8K RING     x7.8        K         24     CRYO VNT LN P     3.1+0    TR       8 COV    0/1         7
      9       DETECTOR BLCK    x2.9        K         25     DEWR VNT LN P     8.2-1    TR       Q DGAS   0/1         8
     10       MIRROR           x7.9        K         26     AMBIENT PRES      6.3-6    TR
     11       FOCAL PLN BOX    x7.9        K         27     SUN SENSOR        3.58     V        VALVE STAT
     12       CRYO 60K RING    x58         K         28     CRYO VT DEL P     4.2-2    TR       V1 CRY   0/1
     13       CRYO 120K RNG    130         K         29     DEWR VT DEL P     4.9-3    TR       V2 DEW 0/1
     14       PLUG DELTA T     +x0.1       K         30     QCM SCIENCE       2.42     V        V9 EXP   OP/CL
     15       CRYO 60K VCS     x58         K         31     QCM INTERNAL T    311      K        V10 PR   OP/CL
     16       CRYO 120K VCS    130         K         32     JFETS TEMP        34.2     K
     FLOW RATES:  F1  122 mg/S     F2  205 mg/S       LAST VALVE CMD V1/2-1/2/3 OP/CL
```

```
GMT DDD/HH:MM:SS.SSS  DP....
     5 OP  05 IRT OPERATIONS
                                  CMD RECD:       DI1     0/1   CNT:   PCU  17495  ECAS     16231
     DI
      1       CMD RECVD        0       SI WORD 1                 WORD 4           CROGEN  STAT          TORR
      2       CMD INTRLCK      0       SCAN LIMITS MD 00         2 SHUTTER        1       CRYO VT       4.2-2
      3       COV OPENED       1       PRIME BCKUP               9 CAL SOURC      0       DEWR VT       4.9-3
      4       COV CLOSED       0       MAX 135.0  135.0          10 SHT CL DR     1                     K
      5       COV LATCHED      0       MIN x90.0  x90.0          11 EMR OP DR     0       DEWR LIQ      x1.8
      6       COV UNLTCHD      1                                 12 CHOP 1 HZ     0       PLUG LIQ      x1.8
      7       STOWED           0       SI WORD 5                 13 CHP 1/4 H     0       DETECTOR      x2.9
      8       UNSTOWED         1       2 ENCODER                 14 SHT CL CD     1       MIRROR        x7.9
      9       SUN ALARM        0       0 PARITY  1               15 COV UNLTD     1
     10       PRES ALARM       1       1 ENC FAILED 0
     11       V10 OPEN         0       2 MOT FAILED 0
     12       POWER ON         1       ANGLE 102.3512
     13       SHTR CLOSED      1
     14       MAX LT SW        0       POS SWITCHES
     15       MIN LT SW        0       DI 15 16 14
     16       CEN POS SW       1           0  1  1
```

Table 3.4-1. Prelaunch Ground Displays (sheet 1 of 2)

ORIGINAL PAGE IS
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ORIGINAL PAGE IS
OF POOR QUALITY

```
GMT DDD/HH:SS.SSS                DP....
      5 SI    005 IRT SERIAL INPUT
                                 CMD RECD:  DI1  0/1      CNT:     PCU      17495    ECAS     16231
      5SI1                       WORDS           2  AND   3
      WD HEX                     P VALVES        EH       POS
      0 HHHH  FILL               15      V1-1 OP X        X
      1 HHHH  SC LT              14        -1 CL X        X
      2 HHHH  V ECH              13      V1-2 OP X        X
      3 HHHH  V POS              12        -2 CL X        X
      4 HHHH  SHUTR              11      V1-3 OP X        X
      5 HHHH  ENCDR              10        -3 CL X        X
      6 HHHH  HT EC               9      V2-1 OP X        X
                                  8        -1 CL X        X
                                  7      V2-2 OP X        X
                                  6        -2 CL X        X
                                  5      V2-3 OP X        X
                                  4        -3 CL X        X
                                  3      V10  OP X        X
                                  2       10  CL X        X
                                  1      V9   OP X        X
                                  0       9   CL X        X




$
```

```
GMT DDD/HH:MM:SS.SSS             DP....
      5 EM    05 IRT EXCEPTION MONITORING
                                 CMD RECD:                DI1             0/1      CNT: PCU          17495    ECAS     16231
      MONITORED                  STATUS                   ENA/INH         ACT      OUT OF LIM

      V1+V2 CLOSED               0/7  0/7                    X             E            *
      V9 OPEN                    OPEN CLOSED                 X             E            *
      V10 OPEN                   OPEN CLOSED                 X             E            *
      CRYOGEN                                                X             E            *
        DEWAR LIQ                XX.X K
        PLUG LIQ                 XX.X K
        CRYO VENT                X.X+X TORR
        DEWR VENT                X.X+X TORR
      CMD RECEIVED               ON/OFF                      X             E            *
        CMD COUNTR               XXXXX
      CMD INTERLOK               ON/OFF                      X             E            *
      5 V POWER                  ON/OFF                      X             E            *

      APPLICATION SOFTWARE                                INITIATE                 @1       ON/
                                                          TERMINATE                @2       OFF
      OUT OF LIMITS                                       RESET                    @3



$
```

Table 3.4-1. Prelaunch Ground Displays (sheet 2 of 2)

ORIGINAL PAGE IS
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```
1234567890123456789012345678901234567890123456789012345677
 50P  5 IRT OPERATIONS           GMT DDD/HH:MM:SS
                            DIS DIS DIS DIS DIS DIS *
   CMD RCVD      XXXXX         THERMAL MONITOR   5TH
 1 BUS PWR          XX         SCAN SYSTEM       5SC
 2 RESET DATA                     TEL TEMP (K)
 3       CONTROL          CRYO INLET            XX
 4 CLOCK SEL         X    FOCAL PLANE           XX
 5 CAL SOURCE       XX    8K RING   XX MRROR    XX
 6     CYCLE (XX)   XX    8K TEL    XX
 7 SHUTTER          XX    60K RING  XX SHADE   XXX
 8    1.00Hz CHOP   XX
 9    0.25Hz CHOP   XX     15 JFETS HTR     XX
10 DOOR LATCH       XX              TEMP    XX K
11        POS       XX                QCM
12        HTR      XXX        CONTAM       XXX ug
13 SUN ALARM↑      XXX     16 DEGAS         XX
14 PRES ALARM↑     XXX        TEMP INT     XXX K
   AMB PRES        XXX uT          EXT     XXX K
IRT MESSAGE LINE
XYZ >EC MESSAGE LINE NN HH:MM:SS EX(NN)
ABC *SC MESSAGE LINE NN HH:MM:SS SS(NN)
              SCRATCH PAD LINE
                                        MAY 27, 1980
```

Table 3.4-2. Aft Flight Deck Display (sheet 1 of 3)

```
 1234567890123456789012345678901234567890123456789012345678901234567
1 5TH  5 IRT THERMAL MONITOR   GMT DDD/HH:MM:SS
2                             DIS DIS DIS DIS DIS DIS *
31 BUS PWR           XX        CMD RCVD   XXXXX |5OP
42 SPACE VENT        XX↑                        |5SC
53       BKUP        XX↑              TEMP (K)
64 VALVE CRYO [0-7]  X          DEWAR LIQ     XX.X↑
75      DEWAR [0-7]  X          VCS INNER     XX.X
8  GAS FLOW CRYO     XX mg          MIDDLE     XXX
9            DEWAR   XX mg          OUTER      XXX
0  LIQ VOL @HH:MM   XXX L       SKIN OUTER     XXX
1  PRES CRYO        XXX↑T       PLUG LIQ      XX.X↑
2       DEWAR       XXX↑T            VAPOR    XX.X
3                                    DELTA     ±.X
46 TC BOX HTR       XXX         CRYO INLET    XX.X
5          TEMP     XXX K       8K RING       XX.X
67 PLUG HTR          XX         60K RING      XX.X
78 EXCEP MON ENA                120K RING      XXX
89            INH
9IRT MESSAGE LINE
0XYZ >EC MESSAGE LINE NN HH:MM:SS EX(NN)
1ABC *SC MESSAGE LINE NN HH:MM:SS SS(NN)
2             SCRATCH PAD LINE
                                             MAY 27, 1980
```

Table 3.4-2. Aft Flight Deck Display (sheet 2 of 3)

ORIGINAL PAGE IS
OF POOR QUALITY

```
 123456789012345678901234567890123456789012345678901234567
1 SSC  5 IRT SCAN SYS/SCAN      [illegible]
2                         DIS DIS DIS DIS DIS DIS *
31 STOW/UNSTOW        XX  |    CMDS RCVD   XXXXX  SOP
42 PIN & SEAL HTR    XXX  |                       5TH
53 SCAN MOTOR         XX  |      SCAN CONTROL
64 MOTOR HTR         XXX  |  9 PRIM/BKUP           XX
7        TEMP        XXX K| 10 BOAA       XXX     XXX
85 SCAN/HOLD          XX  | 11 MANUAL     XXX  <  XXX
9                         |    SHAFT ANGLE        XXX°
06 TACH HTR          XXX  |    POS SWITCH         XXX
17 ELEC 3 HTR        XXX  | 12 MIN SCAN RANGE      XX
28 POS SWTCH OVRD     XX  | 13 MAX SCAN ANGLE      XX
3-------------------------+--------------------------
4          XZ PLN  YZ PLN |     AVOID ANGLE (°)
5SUN        ±XXX    ±XXX  | 14 SUN                XXX
6MOON       ±XXX    ±XXX  | 15 MOON               XXX
7EARTH      ±XXX    ±XXX  | 16 EARTH              XXX
8VEL        ±XXX    ±XXX  | 17 VEL VECTOR         XXX
9IRT MESSAGE LINE
0XYZ >EC MESSAGE LINE NN HH:MM:SS EX(NN)
1ABC *SC MESSAGE LINE NN HH:MM:SS SS(NN)
2               SCRATCH PAD LINE
                                          MAY 27, 1980
```

Table 3.4-2. Aft Flight Deck Display (sheet 3 of 3)

4.0 FACILITIES AND SUPPORT REQUIREMENTS

4.1 INSTALLATION AND ASSEMBLY REQUIREMENTS

The IRT will be delivered to KSC fully assembled except for certain interconnecting cables. It will be mounted on a "pallet" and will remain so mounted until it is transferred to the flight pallet at Level IV. A crane capable of lifting TBD pounds is the only NASA-provided GSE necessary.

4.2 SPECIAL PREPARATION

No special preparations prior to installation are required. The need for pre-installation testing is being studied. If it is deemed necessary, a clean area (equivalent to the cleanliness level of the O&C bay area) will be needed.

Space: TBD x TBD x TBD feet

Electrical Power:

28 VDC: TBD watts, connector type, TBD.

115 VAC: TBD watts, connector type, TBD.

220 VAC: 3, 3-phase, 30-amp, connector type: TBD

Liquid Helium: 500 liters.

Vent Lines for 3 vacuum pumps: Specifications TBD.

In addition, office space for 8 people will be needed.

4.3 ON-LINE ACTIVITIES

4.3.1 Precautions -

No unusual precautions are required in handling the flight hardware.

4.3.2 Special Requirements -

No alignment requirements.

Continuous 115-VAC power (outages not more than five hours long separated by at least TBD hours) is required whenever the instrument is loaded with helium.

4.4 NASA-PROVIDED SUPPORT EQUIPMENT

No special NASA-provided GSE is required.

5.0 PREFLIGHT OPERATIONS REQUIREMENTS

Some time prior to closeout of the Orbiter bay, the IRT dewar must be filled with helium, and the helium cooled to the point where it is superfluid. Because a "soft" vacuum is required to maintain helium in the superfluid state, continuous 115-VAC power must thereafter be supplied to the vacuum pump mounted to the IRT support structure. If the pumping stops, the space above the fluid in the dewar slowly fills with helium gas, the pressure increases, and the liquid temperature rises. After a few hours the liquid helium has warmed to such an extent that it is no longer superfluid. In this state the helium cannot be managed in space; it will pour out of the dewar; and the experiment will be inoperable without its refrigeration.

To prevent this, the IRT has a built-in vacuum pump to maintain the needed vacuum above the fluid. It withdraws gaseous helium from the dewar and dumps it into a vent line that conducts the helium to an appropriate discharge point outside the Orbiter bay. Power outages of up to five* hours in duration can be tolerated, provided there are TBD hours of power-on between outages.

---

*It may be possible to relax this requirement by several hours if the IRT dewar proves to be particularly efficient.

The helium filling and conversion to superfluid require both electrical and mechanical GSE, some of which must be as close to the flight instrument as possible (to minimize the lengths of transfer pipes), but which is rather heavy (on the order of 1,000 pounds).

Filling and conversion operations are estimated to require up to five days. During that time a "hard" vacuum will be established in the dewar and cryostat guard-vacuum spaces. Thereafter no guard-vacuum pumping will be needed. From the end of helium-conversion operations until T-0, the experiment is monitored and controlled by GSE connected via the T-0 umbilical. At the end of the filling and conversion operations several adjustments must be made at the experiment. Transfer lines must be removed, valves closed, relief valves inserted, bias batteries connected to the detectors, and offset resistors adjusted. Experiment power is required for a few hours at that time.

5.1 ACCESS REQUIREMENTS

As described above, access to the experiment for five days as close to final closeout as possible is required. Heavy dewars and pumps must be located close by and hands-on access to the flight system is required.

5.2 SPECIAL SUPPORT REQUIREMENTS

A supply of liquid helium is required. The amount and delivery schedule depend upon detailed scheduling of integration and prelaunch activities.

6.0 FLIGHT REQUIREMENTS

6.1 OPERATING MODES

The IRT will be operated in several "modes."

Activate: Power is applied and the various subsystems are checked out by monitoring both housekeeping and IR data as a series of commands is transmitted. EC software is verified and the cover is unlatched.

Standby: This is the state of the instrument at the conclusion of the activation sequence. The electronics are energized, but the scan-drive motor is off to conserve energy. The system is returned to this state between active observing runs.

Prime Data: This is the celestial infrared observing mode. Orbiter attitudes are required in the -XVV orientations. Several contiguous orbital revolutions must be devoted to IRT operations in each of several roll attitudes. Exclusive observing time is not necessary provided gas and

particulate contamination is not generated by other simultaneous activities or thruster firing activity increased. IRT operation is nearly "automatic" although it must be closely monitored.

Controlled Contamination: IRT data will be taken during such activities as thruster firings to measure their effects on the Orbiter environment.

Coordinated Observing: IR data will be taken in coordination with other Spacelab experiments if the payload complement justifies it. Some special command sequences not used for other IR data taking may be required, to coalign the IRT and some other instrument, for example.

Helium Management: A series of control-valve commands will be issued to adjust the helium-bath temperature and to observe the effects of a variety of management techniques.

Deactivate: This series of activities will normally take place only once, at

the conclusion of the mission. The cover will be closed and latched, the cryostat secured for landing, helium-vent valves adjusted, and power turned off.

In all modes but the second and the last two, aperiodic calibrations may be needed. They are accomplished by closing the cold shutter momentarily. This requires two serial commands spaced by a few seconds. Table 6.1-1 gives some of the major parameters for these modes. Although there are no pointing requirements, certain Orbiter attitudes are necessary (see Section 2.2).

Table 6.1-1
Instrument Operating Mode Requirements

Parameter	Standby Mode	All Other Modes
Power		
28 V instrument	64 watts	367 watts (peak) 172 watts (average)
28 V heaters	10 watts (avg.)	78 watts (max.)
400 Hz	-0-	-0-
Digital Data Downlink	614.4 Kbits/sec	614.4 Kbits/sec
Analog Data Downlink Bandpass	NA	NA
Video Downlink	No	No
Typical Duration	Few Hours	Few Hours
Number of Cycles Required	1	1 each
	More cycles are tolerable, depending upon mission plan	

6.1.1 Typical Timeline Description -

At liftoff the power via the T-0 umbilical to the vacuum pump is removed and the vent line sealed. Once the vacuum of space is reached a barometrically controlled spacevent opens to resume "pumping" on the helium. (A small rise in pressure and temperature is tolerable in the dewar during ascent.) The baroswitch and valve are energized by ascent power.

As soon as the Spacelab is powered up a crew member must verify that the spacevent is open, and if it is not, power up the IRT and command open either the primary or backup valve. This is done be selecting the appropriate item entries on AFD Display 5TH.

To prepare for observing, the normal verification of subsystems precedes the opening of the telescope's vacuum cover. Once the cover is open, sources of contaminating dust and gas, such as water dumps, flash evaporator operations, thruster firings, and effluents from other experiments must be carefully controlled and minimized to keep the Spacelab environment as clean as possible for infrared astronomical observing. A considerable number of valve commands may be necessary both before and after the cover is opened to establish and maintain the correct thermal conditions within the instrument.

Helium flow control valves may also be adjusted from time to time to maintain the desired temperatures during observing sequences. The EC, using the bright-object-avoidance alogorithm (BOAA), calculates the position of sun, moon, earth and velocity vector and when necessary reduces the 90-degree arc over which the telescope scans to prevent these bright objects from shining into the optical system. The Orbiter is in the "airplane" mode, with nose slightly up because orbiting with the velocity vector into the telescope aperture may cause rapid buildup of contaminants. At least three contiguous revs of observing are required with the Z direction close to the local vertical, with the Orbiter rolled 30 degrees right, and 30 degrees left. This sequence of 9 revs is performed at least three times with several days between each sequence.

Later in the mission observations will be continued during flash evaporator exercises, water dumps, and other contaminating events to measure their impact. Also, special observing sequences, coordinated with other Spacelab experiments, may be undertaken.

Finally a series of valve operations will be executed to explore the limits of superfluid helium management in space.

Before reentry the vacuum cover will be closed and the stow pin engaged. However, these are for experimenter convenience and failure of either operation will not jeopardize either the Orbiter or the IRT system. No power is required during reentry except during a launch abort in which case the spacevent is resealed to prevent ingestion of air into the cryogenic system.

Tables 6.1-2 and 6.1-3 show the IRT pointing requirements.

6.2 TARGETS AND VIEWING CONSTRAINTS

Figure 6.2-1 shows field-of-view requirements.

Inasmuch as the IRT is a scanning survey instrument no specific targets are identified. The longest possible observing time is desired, spread over the mission as described in Sections 1.3, 1.4, and 3.

6.3 ANCILLARY PARAMETER REQUIREMENTS

The following parameters are required onboard: UTC, UTCU, State Vector (both AM50 and GTOD). Ancillary parameters are required postmission for thruster activity, flash evaporator operations, and water dumps. See Table 6.3-1.

Table 6.1-2

Pointing Performance Requirements

TBD

Table 6.1-3

Pointing Service Requirements

TBD

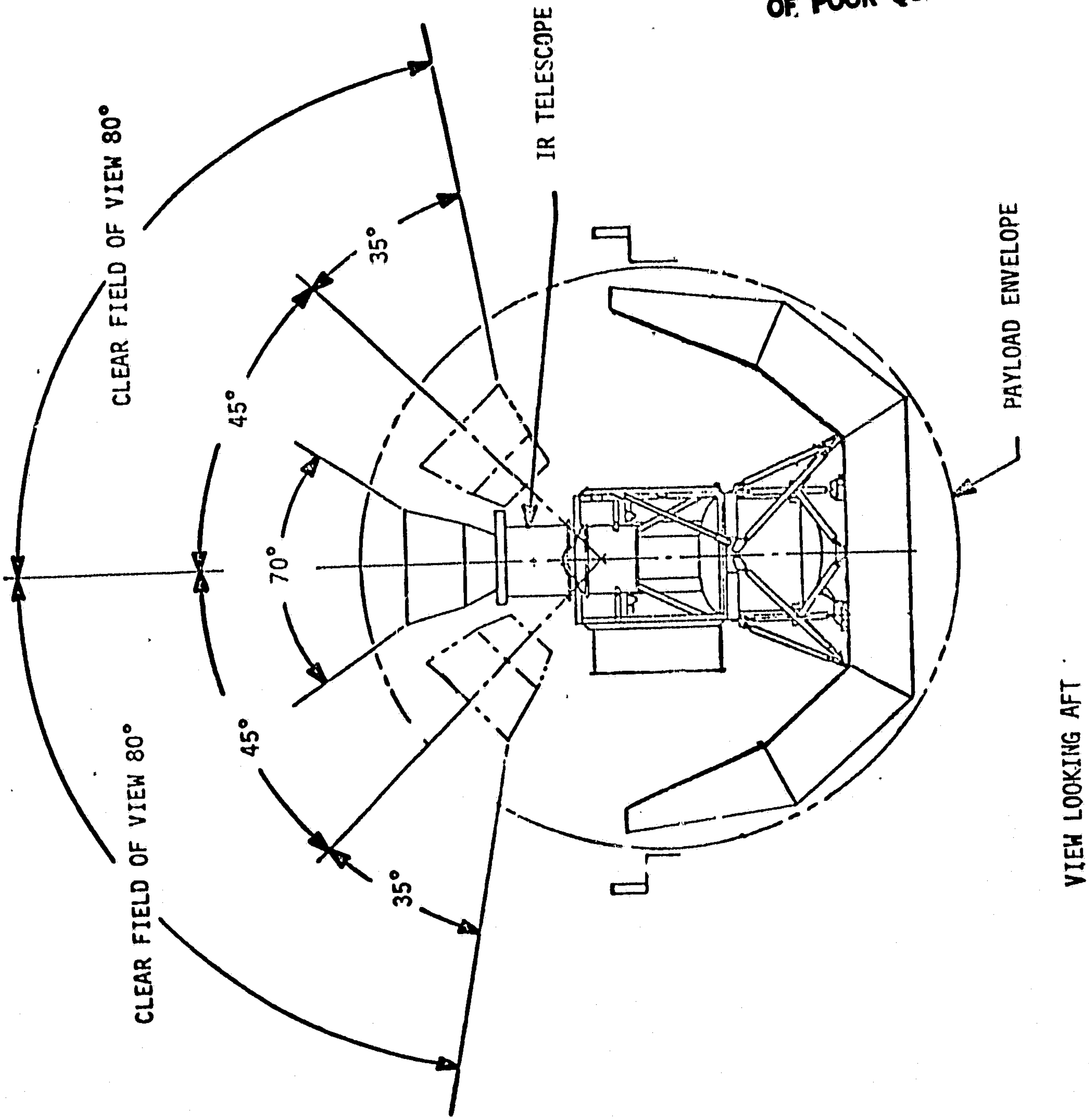

Figure 6.2-1. Telescope Motion Envelope and Clear Field of View

Table 6.3-1
Ancillary Parameter Requirements

Parameter	Onboard	Postmission
Absolute time, UTC (millisec)	Yes	Yes
Orbiter Position (meters)	Yes	Yes
Orbiter Velocity (m/sec)	Yes	Yes
Orbiter Attitude (deg)	Yes	Yes
Other (describe)	Times of flash evaporator activity and water dumps	

GN&C Data Requirements

State Vector	Yes	Either AM50 or GTOD
Current Attitude	Yes	Either AM50 or GTOD
Orbiter Body Rates	Yes	

6.4 FLIGHT ENVIRONMENTAL SENSITIVITY LIMITS

TBD

Table 6.4-1

Flight Environment Limits

TBD

NOTES

1. IRT cannot operate in South Atlantic Anomaly

2. IRT cannot operate when ambient pressure is above 10^{-5} torr.

3. IRT is highly sensitive to H_2O and CO_2. Emission of these molecules must be held to an absolute minimum during the astronomy portion of IRT activity.

6.5 VEHICLE MOTION LIMITS

When the IRT is not taking data (either off or in standby) there are no motion limits short of destructive accelerations.

When the IRT is taking data variations in the rotation rates must be less than 0.006 degrees/sec per axis. Pitch rate is to be 0.067 degrees/sec, roll and yaw rates are to be 0.0 degrees/sec.

6.6 PAYLOAD SPECIALIST REQUIREMENTS

The Payload Specialist serves as a backup to POCC-generated instrument control except for one crucial action. As soon after reaching orbit as possible a crew member must verify the opening of the spacevent as described in Section 6.1.1.

6.7 SPECIAL SUPPORT REQUIREMENTS

No special support is required.

7.0 POSTFLIGHT EQUIPMENT REQUIREMENTS

7.1 ACCESS

No special access is required. Dust covers and vent-line caps should be reinstalled as soon as possible after the payload bay doors are opened. No postmission tests or calibrations are required.

7.2 DEINTEGRATION REQUIREMENTS

TBD

APPENDIX A

IRT-109D, "Command and Housekeeping Definition"

IRT-109

Rev. A	12/05/78
Rev. B	09/25/79
Rev. C	04/30/80
Rev. D	09/20/80 D. Koch

D. Koch

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Small, Helium-Cooled Infrared Telescope

COMMAND AND HOUSEKEEPING DEFINITION

K. Fredholm

November 21, 1978

University of Arizona
Steward Observatory

Marshall Space Flight Center
Space Sciences Laboratory

Smithsonian Institution
Astrophysical Observatory

60 Garden Street
Cambridge, Massachusetts 02138

COMMAND AND HOUSEKEEPING DEFINITION

IRT-109

I N D E X

IRT-109

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Change Log

Revision D -- September 20, 1980

Pages	Change
i	Page 9 became 10, 10-12 became 11-13, 13 combined with 6-7, 15 became 14, 16 not shown became 15.
1	DO24 and 25 pulsed mode deleted. DO 7, 8 and 32 added as pulsed. Added AI14 can be negative. Specified JA-030E. Changed SN to SC. Added comments on Motor CMDS and Command Received Indicator.
2,3,4	Added † and [] footnotes. Identified and/or added corroborative housekeeping. Added item entries to ECAS display. Changed SN to SC. Added EM to DO's 9, 27 and 28.
5	Identified DO's affecting DI1. Changed various ECAS displays. Added EM to DI9 and 10. Added †† footnote.
6,7	Combined previous pages 6 and 7 with pages 13 and 14. AI14 changed to plug delta temp. Updated displays, location, type, calibration, and range.
8	For SO2 defined two different formats. For SO3 defined format having two words.
9	Formerly part of page 8. Defined format having two words. Identified the second word as having two messages. Defined ECAS display and item entries. Named the valves. Expanded the footnote.
10	Formerly page 9 in Rev. C. Added notes 5, 6, and 7. Deleted IIA reference. Added information to words 3, 5, 6 and 7.
11	Formerly page 10. Defined acronyms MFS and DCR.
12	Formerly page 11. Added "by one step" to A.4. Spelled out F/F in D.1 and E.2.

Change Log,
continued

Revision D -- September 20, 1980

Pages	Change
13	Formerly page 12. Added to EL-2, 1. and 3.; EL-1, 3.; and note.
14	Formerly page 15. Under function identified the source, i.e., DO or DI. Changed +, - and zero to MAX, MIN and Center, respectively.
15	Formerly page 16. Interchanged order of columns. Added DI reference. Changed +, - and zero to MAX, MIN and Center, respectively.

IRT-109

Change Log

Revision C -- April 29, 1980

Page	Change
1	Definitions added.
2	IIA references deleted. DO and DI designations added. DO1 and DO2 not used in SL-2. DO3,7,8 added housekeeping. DO7,8 changed to pulsed.
3	IIA references deleted. DO, DI, AI and SI designations added. DO17 Thermal Control Enclosure. DO18 On (Focal Plane Array). DO19 On. DO20, AI19 (T19). DO21 Stow Pin (set to -25°C). DO22 EL-3 Box (set to 0°C). DO26 On.
4	DO32 Control Reset
5	DI1 (Reset by end of SHK readout) DI12 +5V Sense
8	SO1,2 reference added. **footnote added. I.D. bits identified.
9	Notes 3 and 4 added. WD5 changed to unlatched. UTCU changed to UCSU.
10	Reset functions revised throughout.
13	Analog input definition added.
16	Limit switch truth table added.

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COMMAND AND HOUSEKEEPING DEFINITION

General Comments

Definitions -- Inputs and outputs are named as "viewed" by the Experiment Computer. Hence commands are outputs, housekeeping signals are inputs.

Discrete Commands (DO) -- All discrete commands are to be considered to be latched level commands unless otherwise specified. Commands 1, 2, 7, 8, 29 and 32 will be pulsed commands. Command 9 is used with commands 7 and 8. A pulse command is typically of 100 ms duration. Rev. D

Discrete Inputs (DI) -- All levels are 5 V CMOS compatible. A '1' defines the active state.

Analog Inputs (AI) -- All signals are 0-5.06 V full scale -- 7-bit resolution step size = 40 mV except AI14, which can be negative. Rev. D

References: SPAH Appendix A -- Section 4.0, Command and Data Management Subsystem

SL-2 IIA for Experiment 5 (JA-030E) -- Section 4.0, Electrical Rev. D

Section 6.0, Command and Data Management

ECAS Display -- ECAS pages OP for Operations, TH for Thermal Monitor, and SC for SCAN SYS/BOAA. EM indicates ECOS or permanent ECAS exception monitor.

Motor CMDS -- More than one motor should not be running at a time, not counting the scan drive, due to large current required (TBD AMPS). This includes DO3-6, 10, 11 and SO4. The running time for all but the cover motor is 0.8-1.2 sec for 22 V--32 V, respectively. Rev. D

Command Received Indicator (DI1) -- Responds to pulsed DO's (29 and 32), either edge of level DO's (10, 11, 13-28, 30 and 32) and SO4.

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Discrete Commands*

IRT CMD No.	Function	Housekeeping	ECAS Display-Item Entry	IRT Ref. Dwg. No.	
DO1***	Power On (P)* (Not used on SL-2)	DI12 (+5V Sense) Data Output		1260	Rev. D
DO2***	Power Off (P)* (Not used on SL-2)	DI12 (+5V Sense) No Data Output		1260	
DO3†	Cover Unlatch	DI6,[DI5] SI WD5 P15	OP-10	1200 -- sheet 4	
DO4†	Cover Latch	DI5,[DI6] SI WD5 P15	OP-10	1200 -- sheet 4	
DO5†	Cover Open	DI3,[DI4] HRM DHK Bits 2+10 [Science Data]	OP-11	1200 -- sheet 4	
DO6†	Cover Close	DI4,[DI3]	OP-11	1200 -- sheet 4	
DO7	Backup Unlatch**(P)	SI WD5 P15		1200 -- sheet 4	
DO8	Backup Open**(P)	DI3,[DI4] HRM DHK Bits 2+10 [Science Data]		1200 -- sheet 4	
DO9	Command Interlock**	DI2	EM	1245	
DO10†	Stow	DI1 (Cmd Rcvd) DI7,[DI8]	SC-1	1280	Rev. D
DO11†	Unstow	DI1 (Cmd Rcvd) DI8,[DI7]	SC-1	1280	
DO12	HRM Clock Select	Non-Detector HRM Data	OP-4	1250	
DO13	Scan	DI1 (Cmd Rcvd) [DI14,15,16 (Switches)] HRM DHK Bits 0+8	SC-3	1280	
DO14	Scan Zero Rate	DI1 (Cmd Rcvd) HRM DHK Bits 1+9	SC-5	1280	
DO15	Backup Shutter Open	DI1 (Cmd Rcvd) SI WD5 P11 HRM DHK Bits 4+12 [Science Data]		1245	
DO16	Cal Source On	DI1 (Cmd Rcvd) SI WD5 P9 HRM DHK Bits 3+11 [Science Data]	OP-5,6	1245	

*Level commands unless noted with (P) -- pulse command.
**Commands 7 and 8 are interlocked by Command 9.
***Power On/Off no longer commandable 4/11/80.
†Only one motor should be running at a time (not including scan drive).
[]Indicates corroborative information. Rev. D

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Discrete Commands*

IRT CMD No.	Function	Housekeeping	ECAS Display Item Entry	IRT Ref. Dwg. No.
D017	Heater 1 (Thermal Control Box)(10 W)***	DI1 (Cmd Rcvd) SI WD7 P9 [AI20 (T20)(set to 0°C)]	TH-6	1270
D018	Heater 2 JFETS	DI1 (Cmd Rcvd) SI WD7 P10	OP-15	1270
D019	Heater 3 (Porous Plug) (1/8 W)	DI1 (Cmd Rcvd) SI WD7 P11 [AI5 (T5), AI6 (T6)]	TH-7	1270
D020	Heater 4 (Scan Motor)*** (20 W)	DI1 (Cmd Rcvd) SI WD7 P12 [AI19 (T19)(set to 0°C)]	SC-4	1270
D021	Heater 5 (Ferrofluidic Seal)*** (10 W) (Stow Pin)*** (5 W)	DI1 (Cmd Rcvd) SI WD7 P13 (set to -20°C) (set to -25°C)	SC-2	1270
D022	Heater 6 (EL3 Box)*** (10 W)	DI1 (Cmd Rcvd) SI WD7 P14(set to 0°C)	SC-7	1270
D023	Heater 7 (Tachometer)(10 W)*** (Encoder)(10 W)***	DI1 (Cmd Rcvd) SI WD7 P15 [AI19 (T19) (set to 0°C)]	SC-6	1270
D024	Sun Sensor (Override/Reset)	DI1 (Cmd Rcvd) [AI27 (Sun Sensor)] DI9	OP-13	1280
D025	Ion Gauge -- P4 (Override/ Reset)	DI1 (Cmd Rcvd) [AI26 (P4) Ion Gauge] DI10	OP-14	1280
D026	QCM De-Gas Heater On	DI1 (Cmd Rcvd) SI WD7 P8 [AI30 (QCM)] [AI31 (T24)]	OP-16	1270
D027†	V9 Open (Backup Space Vent)	DI1 (Cmd Rcvd) SI WD3 P1	TH-3,EM	1245
D028†	V9 Close (Backup Space Vent)	DI1 (Cmd Rcvd) SI WD3 P0	TH-3,EM	1245
D029	Data Reset (P)	DI1 (Cmd Rcvd)	OP-2	1250
D030	Heater 8*** (Latch Motor)(5 W)*** (Cover Motor)(5 W)***	DI1 (Cmd Rcvd) SI WD7 P7 (Set to -25°C)	OP-12	1280

Rev. D

*Level commands unless noted with (P) -- pulse command.
***Thermostat controller.
†Only one motor should be running at a time (not including scan drive).
[] Indicates corroborative information.

Rev. D

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Discrete Commands*

IRT CMD No.	Function	Housekeeping	ECAS Display-Item Entry	IRT Ref. Dwg. No.
DO31	Backup Limit Switch Override	DI14,15,16 (Switches)	SC-8	1200 -- sheet 4
DO32	Control Reset (P)	DI1 (Cmd Rcvd) [DI13, SI WD2,3,5]	OP-3	1245

Rev. D

*Level commands unless noted with (P) -- pulse command.
[ ] Indicates corroborative information.

Rev D

Discrete Inputs

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Input No.	Function	Type	ECAS Display	IRT Ref. Dwg. No.	
DI1	Command Received (for DO's 10,11, 13-30,32 and SO4)	Acknowledge (Reset at 1 Hz by end of SI Readout)	OP,TH, SC***	1260	Rev. D
DI2	Command Interlock	DO9, Cmd Echo	EM	1200 -- sheet 4	
DI3	Cover Opened**	Position Sense	OP	1280	
DI4	Cover Closed	Position Sense	OP	1200 -- sheet 4	
DI5	Cover Latched	Position Sense	OP	1200 -- sheet 4	
DI6	Cover Unlatched	Position Sense	OP	1200 -- sheet 4	
DI7	Stowed	Position Sense	SC	1280	
DI8	Unstowed	Position Sense	SC	1280	
DI9	Sun Alarm*	Latched Indicator (Reset or Override with DO24)	OP,EM	1280	Rev. D
DI10	Pressure Alarm*	Latched Indicator (Reset or Override with DO25)	OP,EM	1280	
DI11	V10 Status -- Open (Ascent Pwr)	Position Sense	TH,EM	1200 -- sheet 5	
DI12	Power On	+5V Sense††		1260	Rev. D
DI13	Shutter Closed**	Driver Enabled	OP	1245/80	
DI14†	Max Limit Switch**	Position Sense	SC	1280	
DI15†	Min Limit Switch**	Position Sense	SC	1280	Rev. D
DI16†	Center Position Switch**	Position Sense	SC	1280	

*Closes cover and shutter, and commands the telescope to zero rate when the threshold is exceeded. Shutter closure may be prevented by DO15 -- Backup Shutter Open.
**Also available in HRM Digital Housekeeping Word.
***Exception monitored during integration but not mission.
†Refer to Limit Switch Truth Table, pg. 15, for explanation.
††Could be used as AI to measure 5 V output. Rev. D

Analog Inputs

Signal	Device	Location	Type	Calibration	Range (0-5 V)	Comment	ECAS Display	IRT Ref. Dwg. No.
AI1	T1	Dewar Liquid	Ge	Exp	1-5K		TH, EM	1200 -- sheet 8
AI2	T2	Dewar 20K VCS	Diode	Polynomial	15-50K		TH	" "
AI3	T3	Dewar 60K VCS	Pt	Exp	40-100K		TH	" "
AI4	T4	Dewar 120K VCS	Pt	Exp	80-160K		TH	" "
AI5	T5	Porous Plug Liquid	Ge	Exp	1.5-5K	H3	TH, EM	" "
AI6	T6	Porous Plug Vapor	Ge	Exp	1.5-5K	H3	TH	" "
AI7	T7	Cold Finger Inlet	Ge	Exp	1-5K		OP, TH	" "
AI8	T8	Cryo 8K Ring	Ge	Exp	5-20K		OP, TH	" "
AI9	T9	Detector Block	Ge	Exp	2.5-8K	H2	OP	1340
AI10	T10	Mirror	Carbon		4.2-20K		OP	1340
AI11	T11	Focal Plane Box	Carbon		4.2-20K		OP	1340
AI12	T12	Cryo 60K Ring	Pt	Exp	40-100K		OP, TH	1200 -- sheet 8
AI13	T13	Cryo 120K Ring	Pt	Exp	80-160K		TH	" "
AI14	T14	Plug delta T	Ge	Linear	±2K	H3	TH	" "
AI15	T15	Cryo 60K VCS	Pt	Exp	40-100K			" "
AI16	T16	Cryo 120K VCS	Pt	Exp	80-160K			" "
AI17	T17	Cryo Vent	Pt	Linear	225-325K			" "
AI18	T18	Dewar Vent	Pt	Linear	225-325K			" "

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Rev. D

Analog Inputs

Signal	Device	Location	Type	Calibration	Range (0-5 V)	Comment	ECAS Display	IRT Ref. Dwg. No.
AI19	T19	Scan Drive	Pt	Linear	100-350K	H4	SC	1200 -- sheet 8
AI20	T20	Thermal Cont. Box	Pt	Linear	100-350K	H1	TH	" "
AI21	T21	Dewar Shell	Pt	Linear	100-350K		TH	" "
AI22	T22	Sunshade	Pt	Linear	100-350K		OP	1340
AI23	T23	QCM Ambient	Pt	Linear	100-350K		OP	1340
AI24	P1	Cryo Vent Line	Thermistor	Log	0.1-100 Torr		TH, EM	1200 -- sheet 8
AI25	P2	Dewar Vent Line	Thermistor	Log	0.1-100 Torr		TH, EM	" "
AI26	P4	Thermal Cont. Box	Cold Cathode	Log	10^{-7}-10^{-3} Torr		OP	
AI27	Sun Sensor	Sunshade	PIN Si	Linear	0-5 V	Science Data		1350
AI28	ΔP1	Cryo Vent Orifice	Capacitance	Linear	0-1 Torr	Need AI17,24	TH	1200 -- sheet 8
AI29	ΔP2	Dewar Vent Orifice	Capacitance	Linear	0-1 Torr	Need AI18,25	TH	" "
AI30	QCM	Cryostat Shell	Crystal Oscillator	Linear	0-5 V	Science Data	OP	1350
AI31	T24	QCM Internal	Pt	Exp	100-350K	QCM De-Gas Heater	OP	1340
AI32	T25	JFETS	Carbon	Linear	7.2-300K		OP	1340

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Rev. D

Serial Commands

S01. GMT

Format -- 5 16-bit words

S02. State Vector

Format -- AM50 31 16-bit words
GTOD 29 16-bit words

Ref.: IPRD
SPAH, Appendix A

S03. Scan Limits (ECAS display SC Item Entries 9, 10, 11) Rev. D

Format -- 2 16-bit words
WD0 STSW header

Bits

	MSB			LSB
WD1	0	1 - 7	8	9 - 15
	MODE	Θ_X, MAX	MODE	Θ_X, MIN

Rev. D

$0 < \Theta_X < 180°$ LSB = 1.40625° $\Theta_X = 90°$ at +z axis, $\Theta_X = 0°$ at +y axis

BIT 0	BIT 8	MODE	Θ_X RANGE
0	0	PRIME	45°-135° VARIABLE
0	1	BACKUP	45°-90° FIXED **
1	0	BACKUP	90°-135° FIXED **
1	1	BACKUP	45°-135° FIXED **

**Bits 1-7 and 9-15 ignored in backup mode.

Serial Commands

S04. Commutated Command

Format -- 2 16-bit words
WD0 STSW header, WD1 as follows:

Bits (MSB = bit 0, LSB = bit 15)

	Type	ECAS Display Item Entry	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MSG0	Shutter	OP-9,8,7,(6)	0	0	X	X	X	X	X	X	X	X	X	X	CHOP ¼ Hz	CHOP 1Hz	CLOSE	X
MSG1	Valve*	TH-2,5,4	1	0	V10 CLOSE	V10 OPEN	V2-3 CLOSE	V2-3 OPEN	V2-2 CLOSE	V2-2 OPEN	V2-1 CLOSE	V2-1 OPEN	V1-3 CLOSE	V1-3 OPEN	V1-2 CLOSE	V1-2 OPEN	V1-1 CLOSE	V1-1 OPEN
			I.D. Bits		Primary Vent Line		Dewar Valve						Cryostat Valve					

*Only one (1) valve is to be actuated at a time. On time for motors is 0.8-1.2 sec. Sending another valve command before previous valve has completed actuation will result in first valve being stopped in an intermediate state, and execution of the second valve actuation.

Rev. D

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Serial Inputs

(Data Request Synchronous with UCSU)

Bits (Note 4)

SI1 (Note 7)	ECAS Display	0 (MSB)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 (LSB)	
WD1 Timing Word		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Note 2
WD2 Scan Limit Cmd Echo	SC	BU/PRI	←			DATA			→	BU/PRI	←			DATA			→	Note 5
WD3 Valve Controls Cmd Echo		V9 CLOSE DO28	V9 OPEN DO27	V10 CLOSE	V10 OPEN	V2-3 CLOSE	V2-3 OPEN	V2-2 CLOSE	V2-2 OPEN	V2-1 CLOSE	V2-1 OPEN	V1-3 CLOSE	V1-3 OPEN	V1-2 CLOSE	V1-2 OPEN	V1-1 CLOSE	V1-1 OPEN	Note 1
WD4 Valve Positions	TH	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	Note 1
WD5 Shutter Cmd Echo	OP	X	X	X	X	X	X	X	X	X	CAL DO16	CLOSE DRIVE	EMER OPEN DO15	CHOP 1 Hz	CHOP ¼ Hz	CLOSE CMD	UN-LATCH-ED	Note 3
WD6 Scan Encoder Position	SC	PARITY	ENC FLD	MTR FLD	MSB ←		DATA			RANGE 0°	----	180°					LSB →	Note 6
WD7 Heater Cmd Echo	TH	X	X	X	X	X	X	X	H8 COVR DO30	QCM DEGAS DO26	H1 TCB DO17	H2 JFET DO18	H3 PLUG DO19	H4 SCAN DO20	H5 PN/SL DO21	H6 EL3 DO22	H7 TACH DO23	

X = don't care

Note 1: V1-1,2,3: Cryostat Proportional Valve
V2-1,2,3: Dewar Proportional Valve
V9 or V10 Open Position and V1+V2 combination exception monitored, V9 and V10 by ECOS, V1+V2 by permanent ECAS.

Note 2: SI1 (Timing Word) -- used to synchronize RAU Formatter Timing -- Ref. IRT-1230.

Note 3: Bit 15 indicates cover latch position (proximity switch).

Note 4: A parity bit is added to each of the above words before transmission to the RAU (17 bits total).

Note 5: See SO3 for bit definition.

Note 6: Parity (for Bits . 15 only) includes encoder failed and motor failed.

Note 7: Note the word numbering in the IIA is from 0 to 6.

Rev. D

Rev. D

Rev. D

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Reset Functions (D029, D032)

Data Reset (D029)* is used to initialize or resynchronize all HRM Timing and RAU Serial PCM Data functions. It is or'ed with (IRT-1250) internal resets and distributed as follows:

1. Resets divide by 5 counter (IRT-1250) for 204.8 KHz clock.
2. Develops all of the following outputs:
   - A. MFS, Major Frame Synch — Rev. D
   - B. 1 Hz
   - C. RAU Sync
   - D. DCR, Discrete Command Received — Rev. D
   - E. RAU Reset
   - F. HRM Reset #1, 2, 3
   - G. Major frame reset #1, 2, 3

The following page describes the function of item #2 (A-G) in greater detail and references IRT drawing numbers where logic level information may be found.

*or'ed with D029 are the following:
(1) loss of UCS (40 μs pulse)
(2) loss of UCSU (40 μs pulse)
(3) power on Initialize

		IRT Ref. Dwg. No.	
A.	MFS		
1.	Resets format enable counter	1220	
2.*	Resets GMT readout	1242	
3.*	Swaps state vector registers if new data has been received	1243	
4.*	Clocks shutter/cal source counter by one step	1245	Rev. D
B.	1 Hz		
1.	Resets minor frame counter	1220	
C.	RAU Sync		
1.*	Sets PCM request on trailing edge	1230	
D.	DCR		
1.*	Clocks command received flip flop	1260	Rev. D
E.	RAU Reset		
1.*	Resets GMT readout	1242	
2.*	Resets PCM request flip flop	1230	Rev. D
F.	HRM Reset -- #1, 2, 3		
1.	Resets 4 conversion delay counter	1220	
2.	Resets format counter	1220	
3.	Resets FIFO output stage	1330	
G.	Major Frame Sync #1, 2, 3		
1.	Resets conversion timing		

*From HRM receiver on Ch 1 only

Control Reset (D032) is used to clear serial command registers and the shutter/cal source counter in EL-2, and to provide a buffered reset output from EL-2 to EL-1 for scan function resetting. A power on initialization circuit is also or'ed with D032 to provide identical operations automatically. These operations are as follows:

EL-2		IRT Ref. Dwg. No.	
1.*	Clears shutter cmd register, i.e. 1/4 and 1 Hz chop and close cmds set to zero	1245	Rev. D
2.*	Presets shutter/cal source counter to zero	1245	
3.*	Resets all valve cmd registers, i.e. V1, V2 and V10 set to zero	1245	Rev. D
4.**	Reset output to EL-1	1200 -- sheet 2	

EL-1

EL-1 Reset**

Reset is or'ed with an internal power on initialize (~120 ms) to accomplish the following: MSFC 42A20106

1. Immediately inhibits scan cmd disabling motor drive.

2. Resets scan cmd delay counter (2-second delay).

3. Initializes scan command register to full scan backup mode. SI WD2 will indicate backup full scan. Rev. D

4. Resets counters used for scan turnaround indicator pulses.

Note: Scanning will resume in the full scan backup mode unless new S03 received 2 seconds after reset is removed if D013 = 1 and D014 = 0. Rev. D

*From HRM receiver on Ch 1 only
**From HRM receiver on Ch 2

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HRM DIGITAL HOUSEKEEPING

	Byte #N								Byte #N+1							
Bit Nos. →	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

	Byte #N	Byte #N+1 (Note 1)
Used in HRM formats #2 and #3 only	7	8
	31	32
	55	56
	79	80
	105	106
	129	130
	153	154
	177	178

****

	Bit #	Function	State Definition	
	0 + 8	Scan, DO13	"1" = Scan On	"0" = Scan Off
	1 + 9	Scan Zero Rate, DO14	"1" = On	"0" = Off
	2 + 10	Cover Opened, DI3	"1" = Opened	"0" = Closed
	3 + 11	Cal Source On, DO16	"1" = On	"0" = Off
	4 + 12	Shutter Closed, DI13	"1" = Closed	"0" = Opened
(Note 2)	5 + 13	MAX Limit Switch, DI14	"1" = Closed	"0" = Opened
(Note 2)	6 + 14	MIN Limit Switch, DI15	"1" = Closed	"0" = Opened
(Note 2)	7 + 15	Center Position Switch, DI16	"1" = Closed	"0" = Opened

Rev. D

Notes

1. Byte #N+1 is a repeat of data in byte #N. This data is updated 8X per minor frame in the locations identified in the table above.
2. Closed limit switch indicates that the switch cam is in contact at that position. Limit Switch Truth Table on next page.
3. IRT Ref. Dwg. No. 1280 (Scan Control)

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LIMIT SWITCH TRUTH TABLE

MIN LIMIT DI15 BIT 6/14	CENTER POS DI16 BIT 7/15	MAX LIMIT DI14 BIT 5/13	TELESCOPE POSITION (DEGREES)
0	1	1	45
0	0	1	45 — 90
1	0	1	90 (center)
1	0	0	90 — 135
1	1	0	135

Rev. D

APPENDIX B

IRT-116, "HRM Format Description"

IRT-116

Small Helium-Cooled Infrared Telescope

HRM FORMAT DESCRIPTION

K. Fredholm

Smithsonian Astrophysical
Observatory

2 October, 1979

University of Arizona
Steward Observatory

Marshall Space Flight Center
Space Sciences Laboratory

Smithsonian Institution
Astrophysical Observatory
60 Garden Street
Cambridge, Massachusetts 02138

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SYNC CODE AND FRAMF NO.

	BYTE #1								BYTE #2								BYTE #3								BYTE #4							
Bit Nos. →	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
Data →	1	1	1	1	1	0	1	0	1	1	1	1	0	0	1	1	0	0	1	0	0	0	0	0								

24-Bit Sync Code (76571440 -- Octal)
Jumper selectable on format control card
(IRT-1220)
specified as shown above
in IIA, Fig. 6-1

BIT 25 -- Spare Bit
Jumper Selected to "0"
(IRT-1220)

BITS 26-32 -- Minor Frame No.

Bit 28 = MSB	Bit 1	MF# $0 \rightarrow 127$
29 =	Bit 2	
30 =	Bit 3	
31 =	Bit 4	
32 = LSB	Bit 5	

GMT

Ref: IRT-1242 -- GMT CMD BUFFER, Rev. ___
SPAH, APPENDIX A -- Issue 1, July 31, 1978
MSFC-STD-630, April, 1979
SPACELAB HIGH RATE MULTIPLEXER FORMAT STANDARDS

	LOCATION WITHIN FRAME: BYTE #5	LOCATION WITHIN FRAME: BYTE #6
Minor Frame 0	EXPERIMENT ID.	MODE (CH ID.)
" " 1	MISSION ID.	GMT #1
" " 2	GMT #2	GMT #3
" " 3	GMT #4	GMT #5
" " 4	GMT #6	DATA 1
" " 5	DATA 2	DATA 3
↓ Minor Frame 31	(NOTE) ALL ZEROES	(NOTE) ALL ZEROES

Note: IRT Ref. Dwg. No. 1242 (GMT Cmd Buffer)

GMT -- MINOR FRAME 0

EXPERIMENT ID. (Byte #5 of Minor Frame #0)

Bit 0 → A (first bit) … Bit 7 → last bit

Bit 0							Bit 7	
A	B	0	0	0	1	0	1	← Binary Data

$\underbrace{A\ B\ 0\ 0\ 0\ 1\ 0\ 1}_{\text{Experiment \#5 ID.}}$

A	B		
0	0	=	HRM Channel #3 (IRT Ch. 1)
0	1	=	HRM Channel #4 (IRT Ch. 2)
1	0	=	HRM Channel #5 (IRT Ch. 3)

****

MODE

(Byte #6 of Minor Frame #0)

with Channel ID.

Bit 0							Bit 7	
0	0	0	0	0	0	A	B	← Binary Data

$\underbrace{0\ 0\ 0\ 0\ 0\ 0}_{\text{Fixed Field}}\ \underbrace{A\ B}$

A	B		
0	0	=	HRM Channel #3 (IRT Ch. 1)
0	1	=	HRM Channel #4 (IRT Ch. 2)
1	0	=	HRM Channel #5 (IRT Ch. 3)

GMT -- MINOR FRAME 1

MISSION ID. (Byte #5 of Minor Frame #1)

Bit 0							Bit 7	
1	1	0	0	1	1	0	A	← Binary Data

Fixed ID. Field for Spacelab 2 Exp. No. 5 (Bits 0 → 6, inc.)

Days of Year Binary - 2^8 (MSB)

****

GMT #1

(Byte #6 of Minor Frame #1)

Bit Nos. →	0	1	2	3	4	5	6	7

Binary

Days of Year -- 2^7 (Bit 0)

" " " -- 2^6 (Bit 1)

" " " -- 2^5 (Bit 2)

" " " -- 2^4 (Bit 3)

" " " -- 2^3 (Bit 4)

" " " -- 2^2 (Bit 5)

" " " -- 2^1 (Bit 6)

" " " -- 2^0 (LSB) (Bit 7)

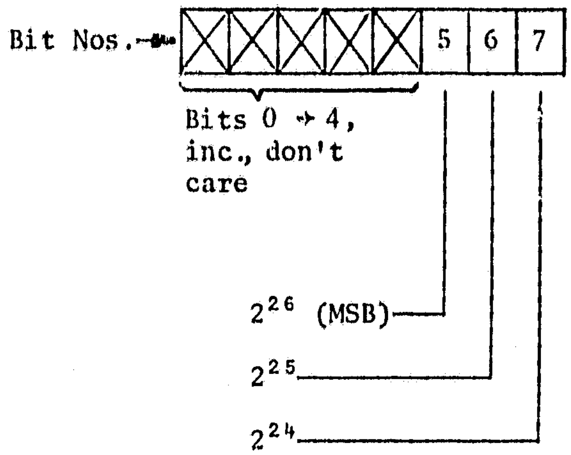
Note: MSB of GMT #1 is included with the mission ID. byte

GMT -- MINOR FRAME 2

GMT #2

(Byte #5 of Minor Frame #2)

Milliseconds of Day
(High Order)

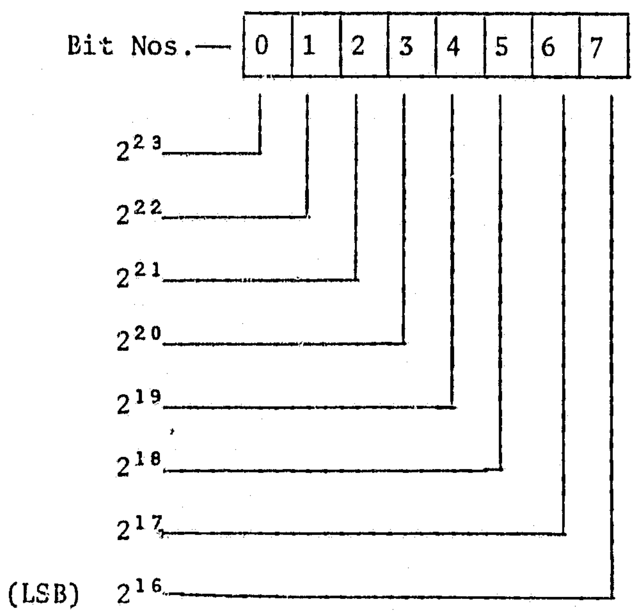


****

GMT #3

(Byte #6 of Minor Frame #2)

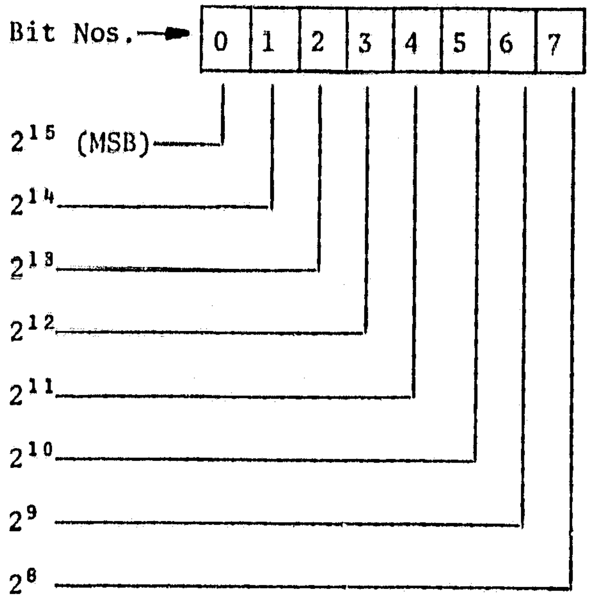
Milliseconds of Day
(High Order)
Binary



GMT #4

(Byte #5 of Minor Frame #3)

Milliseconds of Day
(Low Order)
Binary

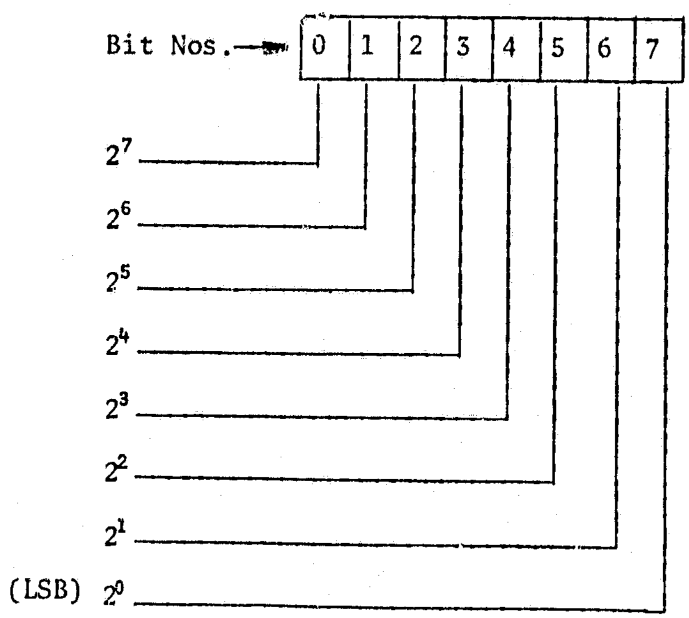


****

GMT #5

(Byte #6 of Minor Frame #3)

Milliseconds of Day
(Low Order)
Binary

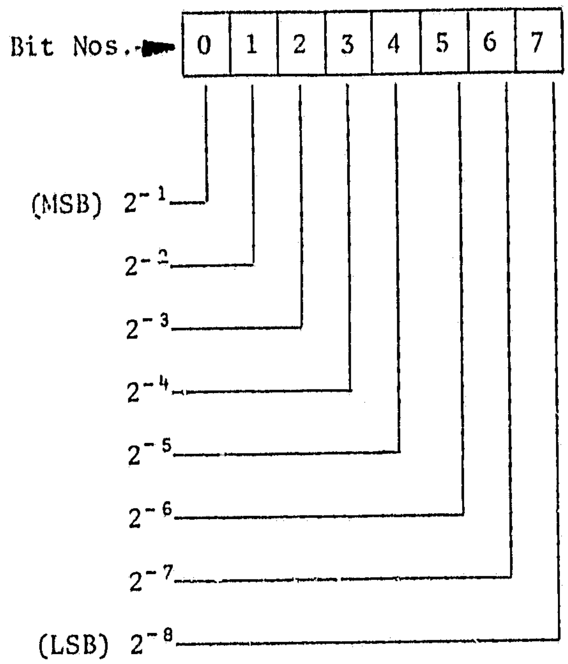


GMT -- MINOR FRAME 4

GMT #6

(Byte #5 of Minor Frame #4)

Fractional Milliseconds
Binary



****

DATA 1, 2, 3, etc.

Contain all zeroes

C-2

DIGITAL HOUSEKEEPING

	Byte #N								Byte #N+1							
Bit Nos. →	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

	Byte #N	Byte #N+1 (Note 1)
Used in HRM formats #2 and #3 only	7	8
	31	32
	55	56
	79	80
	105	106
	129	130
	153	154
	177	178

****

	Bit #	Function	State Definition	
	0 + 8	Cmd 13 (Scan)	"1" = Scan On	"0" = Scan Off
	1 + 9	Cmd 14 (Scan Zero Rate)	"1" = On	"0" = Off
	2 + 10	Cover Opened	"1" = Opened	"0" = Closed
	3 + 11	Cal Source On	"1" = On	"0" = Off
	4 + 12	Shutter Closed	"1" = Closed	"0" = Opened
(Note 2)	5 + 13	(+) Limit Switch	"1" = Closed	"0" = Opened
(Note 2)	6 + 14	(-) Limit Switch	"1" = Closed	"0" = Opened
(Note 2)	7 + 15	Zero Position Switch	"1" = Closed	"0" = Opened

Notes

1. Byte #N+1 is a repeat of data in byte #N. This data is updated 8X per minor frame in the locations identified in the table above.
2. Closed limit switch indicates that the switch cam is in contact at that position.
3. IRT Ref. Dwg. No. 1280 (Scan Control)

LIMITS

	Byte #N								Byte #N+1						
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Used in HRM formats #2 and #3 only:

Byte #N	Byte #N+1
9	10
33	34
57	58
81	82
107	108
131	132
155	156
179	180

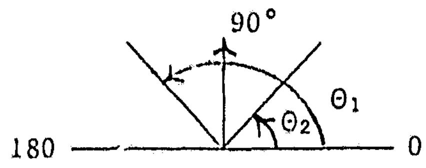
****

Bit #	Function	State Definition
1	Mode (MSB)	See Table 1
2	Θ_X, MAX DATA A (MSB)	"1" = 90.00°
3	" " DATA B	"1" = 45.00°
4	" " DATA C	"1" = 22.50°
5	" " DATA D	"1" = 11.25°
6	" " DATA E	"1" = 5.625°
7	" " DATA F	"1" = 2.813°
8	" " DATA G (LSB)	"1" = 1.406°
9	Mode (LSB)	See Table 1
10	Θ_X, MIN DATA A (MSB)	"1" = 90.00°
11	" " DATA B	"1" = 45.00°
12	" " DATA C	"1" = 22.50°
13	" " DATA D	"1" = 11.25°
14	" " DATA E	"1" = 5.625°
15	" " DATA F	"1" = 2.813°
16	" " DATA G (LSB)	"1" = 1.406°

****

LIMITS, Cont.

Note: Range of Θ_X, MIN/MAX $0° \rightarrow 178.594°$ in steps of $1.406°$ (LSB)



$\Theta_1 = \Theta_X$ MAX

$\Theta_2 = \Theta_X$ MIN

$90° \geq [\Theta_1 - \Theta_2] \geq 20°$ and $\Theta_1 \leq 135°$, $\Theta_2 \geq 45°$

****

Table 1

BIT		MODE	RANGE
0	8		
0	0	Prime	45° → 135° Variable
0	1	Backup	45° → 90° Fixed
1	0	Backup	90° → 135° Fixed
1	1	Backup	45° → 135° Variable

Note: IRT Ref. Dwg. No. 1244 [MSFC Digital Controller (EL-1)]

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SCAN ENCODER

	Byte #N								Byte #N+1							
Bit No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Used in HRM formats #2 and #3 only:

Byte #N	Byte #N+1
11	12
35	36
59	60
83	84
109	110
133	134
157	158
181	182

****

	Bit #	Function	State Definition
	1	PARITY	ODD PARITY
	2	ENCODER FAIL	"1" = FAIL "0" = NORMAL
	3	MOTOR FAIL	"1" = FAIL "0" = NORMAL
See Note	4	DATA 2	"1" = 90°
See Note	5	DATA 3	"1" = 45°
See Note	6	DATA 4	"1" = 22°30' or 22.5°
See Note	7	DATA 5	"1" = 11°15' or 11.25°
See Note	8	DATA 6	"1" = 5°37'30" or 5.625°
See Note	9	DATA 7	"1" = 2°48'45" or 2.813°
See Note	10	DATA 8	"1" = 1°24'22" or 1.406°
	11	DATA 9	"1" = 0°42'11" or 0.7031°
	12	DATA 10	"1" = 0°21'05" or 0.3515°
	13	DATA 11	"1" = 0°10'32" or 0.1757°
	14	DATA 12	"1" = 0°05'16" or 0.0878°
	15	DATA 13	"1" = 0°02'38" or 0.0439°
	16	DATA 14 - LSB	"1" = 0°01'19" or 0.0219°

Note: DATA 2 → DATA 8 are used for scan limit control in EL-1 electronics -- DATA 8 becomes the LSB of the 7-bit word (1.406° LSB). DATA 1 is not used.

DETECTOR DATA

Byte #N								Byte #N+1							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

BITS 4 → 15, inc. -- 12-Bit Detector Data

Bit 5 = MSB, Bit 16 = LSB
Referenced to ADC inputs
(zero) 000 000 000 000 = 0.000 VDC
(F.S.) 111 111 111 111 = -10.000 VDC

BITS 2 and 3 -- Negative Data Flag (Redundant)

Both bits will always contain similar data
"1" = negative data (referenced to preamp inputs)
"0" = positive data (referenced to preamp inputs)

BIT 1 -- Spare Bit/Always = "0"

BIT 0 -- Parity Bit (Maintains odd number of "1's")

"1" = even number of "1's" (bits 2 → 16)
"0" = odd number of "1's" (bits 2 → 16)

STATE VECTOR

		BYTE #103	BYTE #104
Minor Frame	0	OP CODE	ID FIELD
" "	1	TBD	TBD
" "	2	TBD	TBD
	↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	Op code is fixed for both formats	
Minor Frame	30	TBD	TBD
	31		

Ref: IIA, Table TBD
IRT Ref. Dwg. No. 1243

Notes:
1. Data will be in ARIES M50 form (31 words).
2. Minor frame #31 will contain all zeros.